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MAPPING THE POTENTIAL OF RENEWABLE ENERGY IN FINLAND

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The thesis examines the potential of renewable energy in Finland, as a request from Natural Step. Six different renewable energies were studied: wind power, solar power, bioenergy, geothermal heat pumps, hydropower and untapped potential hydropower. This was done regionally in order to see which regions would be the most productive in producing energy from renewable sources mentioned above. Then the actual electrical usage was regionally compared to the potential of renewables that each region has the capacity to produce.

Methodology

Most of the data was collected from the vast resource of the internet. In mapping the potential of renewable energy QGIS was used which is a handy software that has many applications. After collecting the relevant data I set out to map the provinces with their respected output of renewable energy. The data was put into QGIS and from that could make some conclusions on which provinces are the most productive. The method and calculations are explained more in detail in the chapters that will follow.

Keywords	Renewable energy potential, QGIS, wind power, bioenergy, solar power, hydropower, small scale hydropower, geothermal heat pumps, Climate and Energy Strategy

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1 Introduction

With the introduction of the industrial revolution into the western society, the standards of living have improved dramatically compared to the past eons. This has resulted in improved health care and a population growth that has not been seen before, thanks to science I might add. In the industrial society, people have become good at building our environment to our convenience, such as houses, cities, factories, energy production, large scale farming and transfer of information just to name a few. These matters have become so trivial that we take them essentially for granted without a second thought of where they came from. Keeping that in mind, it only becomes evident in inspecting how we behave within and towards nature that there are some matters we do not have control over. The speed of light, gravity, the laws of thermodynamics and the finite resources of the planet are such concepts.

This been said scientists would like to remind us of a mathematical concept that societies are forced to live within and that is the function of the exponential growth. This describes the size of anything that is growing steadily, for example a growth rate of 2% per year. This indicates that the time that it takes for a quantity to grow will do so by a fixed fraction that is constant. It takes a fixed length of time to grow by 100 %, in other words the doubling time. The equation to calculate the doubling time is easy and it follows $t_{doubling} = \frac{70}{\%\, growth\ per\ unit\ time}$. In our example a growth rate of 2 % will mean that in 35 years the quantity will have doubled in size. The attitude that the industrial nations have adopted, that the economy should be growing at a certain percentage within the plain of capitalism and consumption is not a sustainable attitude to the planet and to the society that we live in.

Scientist likes to give the analogy of the test tube with a cultivation of bacteria. The test tube represents our planet with its limited food and resources and the bacteria as the human population. If starting with only one bacterium that doubles in population every minute, at what point will it have taken up half the space of the test tube? The answer is at the 59th minute and in the next minute it will take up the whole space of the test tube. But two minutes before that the test tube was 25% full and before that 12.5% full giving the impression that there is nothing to worry about until it is too late and have exhausted all the resources in the tube. This example tries to illustrate that the world is a finite biosphere that has limited resources to maintain life. If the attitude of the western societies and the next industrial nations (e.g. India and China) is to have a steady economic growth with business as usual, the planet at some point will run out of resources and the well-being of the society will start to decline. The scary part is some scientists agree that we have past the 59th minute and now we are playing with seconds. At this point Natural Step steps in.

Natural step was developed in Sweden in 1989 by the scientist Karl-Henrik Robert. He has developed a method called The Natural Step Framework, which sets out to minimize the impacts of human activity on the environment and a sustainable approach to human activity towards earth. An overview of the frame work is that it has five levels that gives guidance in planning and in decision making within the framework of the whole system. The five levels are:

- *System*
- *Success*
- *Strategic*
- *Actions*
- *Tools*

This approach can be used to analyze any complex system of any type or scale, for example the human body. This helps in planning, decision making and strategically approach the goals that have been set within the framework of the system. When the Five Level Framework (5LF) is applied to the socio-ecological system (or society within the biosphere), it is called the Framework for Strategic Sustainable Development (FSSD) and also known as The Natural Step Framework. The approach helps in giving a model to see the bigger picture of the workings and functions of our ecological, social systems, institutions, current trends and our sustainability challenge. First, what is investigated is how society and its have a negative effect towards the socio-ecological system, this would be the “System”. The next inspection would be what conditions should be met for it not to be negatively influenced as in “Success”. Then to plan towards that success by formulating a strategy the “Strategic” phase with prioritized “Actions” selecting or coming up with designs and applying the appropriate tools for those actions “Tools”.

As an engineer concentrated on renewable energies, my focus in this thesis was to be on the second and third issues in the framework, i.e. Success and somewhat Strategic. The question raised is what are the potentials of Finland to move to a sustainable energy production using renewable energies without compromising the current and future needs of the nation. An investigation will be made by collecting data from different sources as on how much and in what form of renewable energies are out there that are most suitable for Finland given its resources and geographical location. After collecting the data and presenting the data for the most suitable renewable energies an attempt was made to map out (using QGIS) the areas for the best solutions of renewable energies in the regions of Finland in order to help and guide a theoretical transition to renewable energies suited for each region of Finland.

2 Wind power

Finland's first wind power installation was installed by Kauppa-ja teollisuusministeriö at the end of 1980's as a research installation. This led to the project NEMO which was an energy research organization concerned with renewable energies. The research objective was to collect data and the mapping of the average wind speeds in Finland which was given the name Tuuliatlas. In 1991 Kemijoki Oy installed Bonus Energy that produced a wind turbine that had the capacity of 65 kW (Tuulivoima Suomessa 2015).
The first wind farms were built in autumn of 1991 in the municipality of Vaasa near Korsnäs. It consisted of four turbines 200 kW each, which are the oldest functional wind farms in Finland at the current moment. Wind farms caught on between 1991-1993 when in those years there was more wind turbines installed than all the years before that. Many of them were between 300 kW in capacity (Tuulivoima Suomessa 2015).

Since then many other locations were selected and wind farms were built inland and in the Åland regions. The turbines also grew in capacity as the years progressed by 1997 there were installed 500 kW, 600 kW and 750 kW by the end of 1999. Also in that same year 1.3 MW turbines were built in Oulusalon and two same sized turbines were built in Uusikaupungin (Tuulivoima Suomessa 2015).

In the turn of the millennium, Finland started installing 2-3 MW turbines. The first two megawatt turbine was built in Meri-Pori as the ninth turbine. The first three megawatt turbine was built in 2005 in Oulu. In June of 2008 in Dragsfjärd Högsåra three two megawatt turbines were installed, they are owned by Via Wind. The produced electricity is sold by Turku Energy. In its peak hours the turbines can generate 6 MW of power. (Tuulivoima Suomessa 2015)

In 2009 TuuliWati installed its first turbine in Pori Tahkoluoto and at that time it was considered the largest wind turbine in Finland, with a height of hundred meters to the rotary center and with a rotary diameter of 100 meters. TuuliWaties first wind farm was taken to use in 2012 in Simo Putaankanka. In theory the electricity produced from the turbines could supply 20 000 apartments the energy needed. Since then in Iin Olhavas, in 2013 a 140 meter high turbine that can reach to 200 m when the rotary blade is at its highest. Also in the same year in Tervola Varvaras (inland site) 10 turbines were put into use making a contribution of 10 percent to the Finnish windmill production. An inland wind farm was also built in the Tornio municipality that was situated 40 km form the city. By the end of 2014 eight turbines were in production with a capacity of 4.5 megawatts each. Also in the spring of 2014 in Simo four turbines went into production that is considered to be the largest wind turbines in Finland. The height of the turbines to the center of the rotary is 140 m with the blades 204 m. One turbine has the potential to produce in a year the equivalent of 6 000 apartments electricity use. In the same year in Pori Peittooseen the installation of twelve 4.5 MW has begun, when complete this will be the biggest wind turbines used in a wind farm. In Kalajoki another large scale wind farm is in production that will incorporate of 22 turbines consisting on average, 3.3 MW turbines with a combined production of 73 MW, this will be the biggest wind farm that Finland has till this date (TuuliWatti 2015).

In December 2014 wind power capacity in Finland was 627 MW with 260 turbines. In the prior year Finland had 211 wind turbines and their combined capacity was 448 MW. At the end of 2012 Finland had 163 wind turbines and their combined capacity was 288 MW. By the end of 2014 there was published over 10 000 MW of wind power and off shore planned projects an estimate of 2 200 MW (Teollinene tuulivoima Suomessa 2015).

2.1 Mapping potential sites for wind power

In the mapping out of potential wind power, the approach taken was to map out the existing wind turbines and wind farms; also the ones that are in production, under construction, preparing for construction, applying for permits, EIA and spatial planning under consideration and feasibility studied and decision making. As can be seen in the figure 1 below, these are all the sites that fulfill the criteria mentioned above:

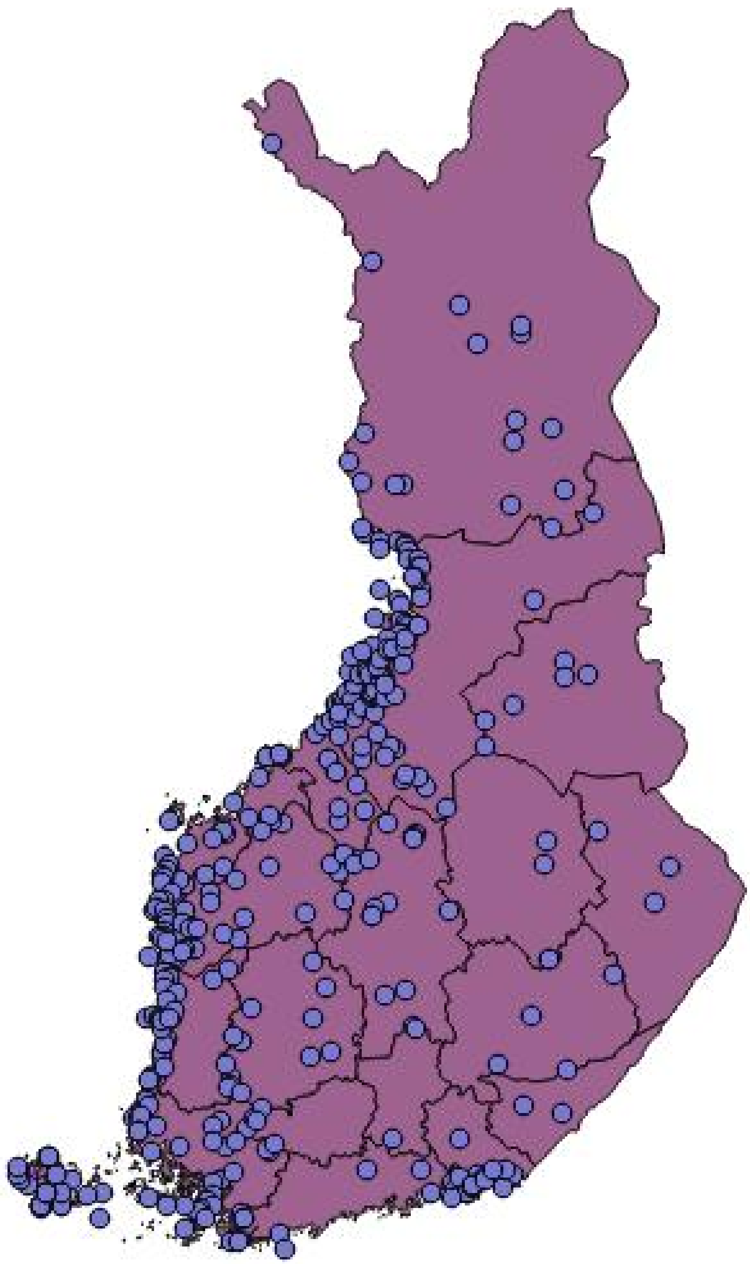

Figure 1. The sites of wind farms and wind turbines in Finland by region.

2.2 Total potential of wind power

In looking at the data it can be seen which regions will generate the most energy output. This of course taken for granted that all the sites in the first figure would be built. The time that would be taken to build all these sites is not taken into consideration. As can be seen the most output will be generated in North Ostrobothnia with a 22.6 PJ of output energy which is the equivalent of 339 901 averaged size households energy use in a year. This would save Finland the equivalent of 1 234 442.9 tons of coal equivalent (TCE) that it would not have to use in the production of energy. The rest of the values can be seen in the appendix 2, also how these values were calculated. The total energy for Finland from wind power is 73.8 PJ. The figure 2 below shows the different regions potential of providing wind energy.

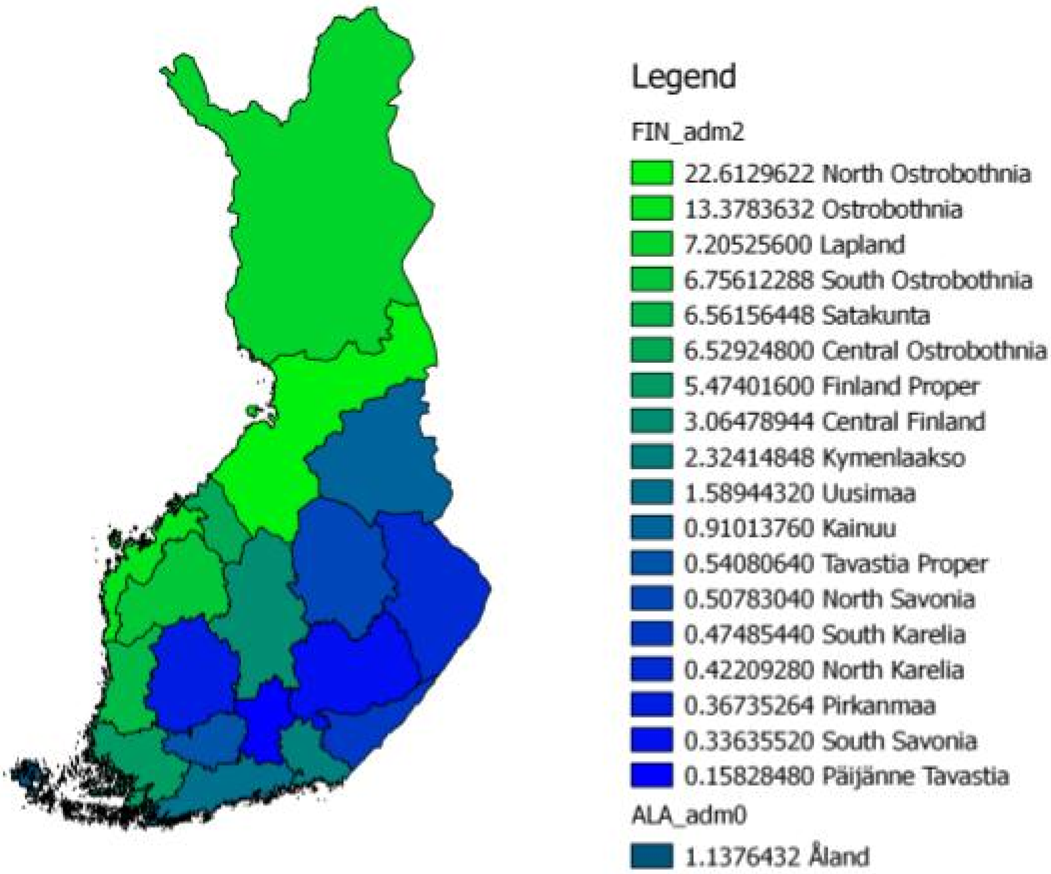

Figure 2. Total wind energy by region in PJ.

3 Potential Solar Power

There are three ways to utilize solar power, the first method is photovoltaic (PV), second method is by solar thermal (ST) and last method is concentrating solar power (CSP). Photovoltaic and concentrating power are used for electricity production and solar thermal systems for heat production (Photovoltaics 2015).

Photovoltaic systems are an electric power that its main function is to convert incoming photons into an electric current by the flow of electrons. This is done by solar panels that are built from multiple solar cells that contain photovoltaic material such as monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Solar cells produce direct current (DC) electricity but to make the electricity more useful in practical applications the current is converted to alternating current by inverters. The development of PV has been increasing at a fast rate which has also resulted in that the price of the modules have come down to affordable levels as the efficiency have improved (Photovoltaics 2015).

Solar thermal energy is a system that captures solar energy and then converts it to heat using water as a medium. These can be seen throughout the Mediterranean region, the Middle East and Asia. ST provide cheap clean hot water for domestic use, these can provide 85 % of domestic hot water energy. In many northern European countries, combined water and space heating systems are used to provide some 15 to25 % of home heating energy. A basic solar thermal system is made up of a thermal collector, a storage tank, some piping and often a pump. These are typically fastened on the roof tops and face the sun to maximize the amount of captured sunlight. Sun heats the working fluid that is either pumped (active system) or driven by natural convection (passive system) through the collector and the rest of the system. Heat is transferred and stored in a hot water storage tank, which vary by size and shape depending on the overall system design and needs. The fluid is most of the time water but can have antifreeze and corrosion inhibitor, for systems that operate in freezing conditions (Concentrated solar power 2015).

Concentrating solar power uses sunlight that concentrates the sunlight several times to reach higher energy densities and thus higher temperatures. Heat is used to operate a conventional power cycle, for example through a steam or gas turbine which drives a generator. CPS's are built in areas that have direct radiation most of the year. CSP plants typically include a thermal storage and an additional back-up power source, they are dispatch able and can be used for both base load production and as a peak power generators (Concentrated solar power 2015).

Concentrated-solar technology systems use mirrors or lenses with tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant (solar thermoelectricity). The solar concentrators used in CSP systems can often also be used to provide industrial process heating or cooling, such as in solar air-conditioning (Concentrated solar power). CSP growth is expected to continue at a fast pace. As of January 2014, Spain had a total capacity of 2,204 MW making this country the world leader in CSP. Interest is also notable in North Africa and the Middle East, as well as India and China. The global market has been dominated by parabolic-trough plants, which account for 90% of CSP plants (Concentrated solar power 2015).

3.1 Potential irradiation in Finland

The yearly irradiation varies within a year which means the amount of radiation fluctuates and is not constant. The most important factor in irradiance is air mass which is used to describe how thick a layer of air solar radiation has to pass to the earth's surface. Because air mass changes between years and days, available power changes also. However, yearly irradiation energy varies much less. Average daily irradiation of 2.4 kWh equals 901.55 kWh over a year. Irradiation in Tampere has been measured by Tampere sähkölaitos, a local utility company during 1985 to 1992. Irradiation in the measurements was between 726.3 and 817 kWh (inclination 0^{o}) (The Finnish solar cluster 2015).

There is somewhat misconception that the Nordic countries have less irradiation than the rest of Europe such as Spain, but when comparing the annual irradiation with a country like Germany the difference is not that significant. Sure there are some months that the Nordic countries receive a small amount or irradiation compared to central Europe but this can be compensated with the fact that PV systems have a better efficiency when they are cool rather when they are hot. One main reason for the high PV capacity in Germany compared to Finland is that they differ in feed in tariff system. Figure below illustrates the difference between certain European cites. It can be seen that on average Helsinki does not differ significantly from Vienna, even though there are some months in the winter that irradiation is considerably less (The Finnish solar cluster 2015).

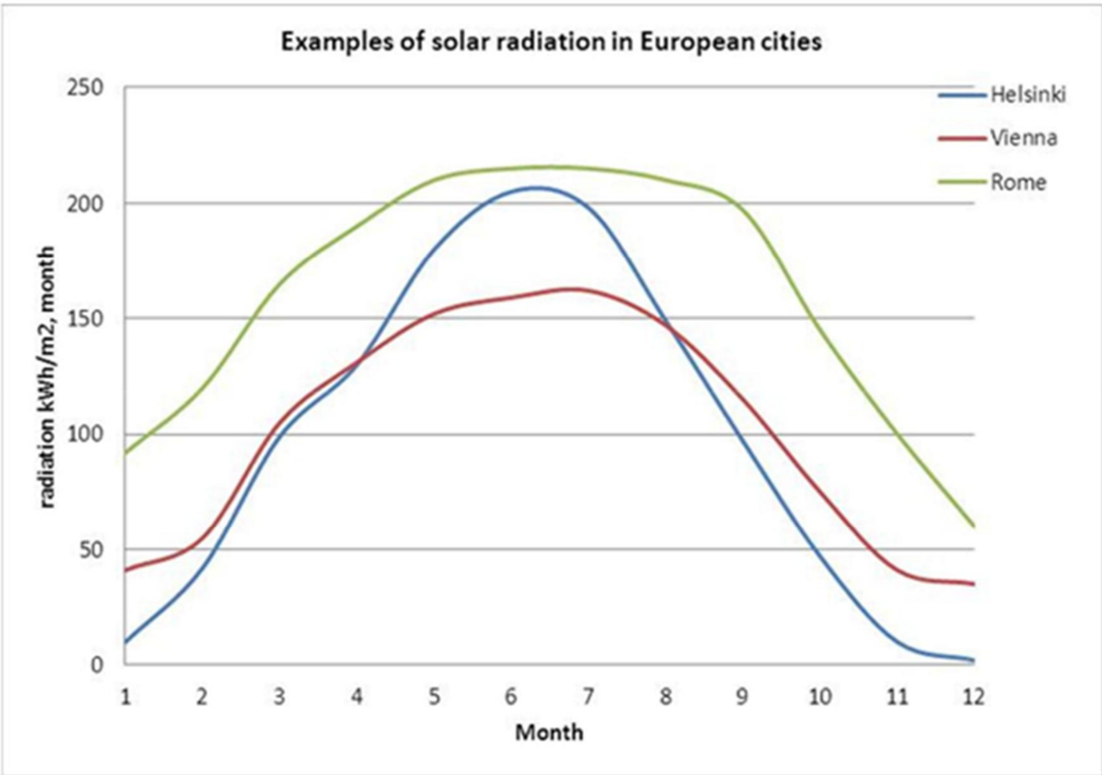

Figure 3. A graph of the radiation in European cities.

One major disadvantage that Finland has compared to rest of Europe is the accumulation of snow in the winter. For the panels have to be clear of snow if they are to function properly. So they have to be cleaned when snow has fallen. One way to tackle this problem is to have a method that prevents snow accumulation on the panels. They can be equipped with hydrophobic coating which reduces friction on the panel's surface for snow (Artic solar energy solutions 2015).

Most of the buildings are residential buildings in Finland. Total residential area was about 273 420 000 m^2 in 2010 (Statistics Finland 2010), where 67% was 1-floor residential buildings, 28% 2-floor and the rest 3-floors or more. Very roughly can be evaluated that the roof area of those buildings is about 244 890 000 m^2. One quarter of that roof area could face towards the right direction for solar harnessing which is roughly 61 222 500 m^2.

3.2 Calculation of solar power in Finland

The approach to calculate the potential of solar power in Finland was to have an educated estimate on how much an area would be used for a PV set up for each region. In this thesis the area was calculated using the data from the amount of total surface area roofs have in Finland in 2010. By taking a ratio of the roof surface and calculating the roof surface area for detached houses in each region it is possible to make a hypothetical estimate on the potential of solar power.

Example:

In this calculation example Uusimaa is the focus as having one of the highest residential housing and population from all the regions. Since the potential area for collecting solar energy is roughly 61 222 500 m^2 roof area for the whole of Finland then calculating the roof area for 1 floored building's is:

61 222 500 $m^2 \times 0.67 =$ 41 019 075 m^2

The ratio of the area of 1 floored detached houses and the whole roof area of Finland is 41 019 075 m^2/244 89 000 m^2 = 0.1675. This means that each region has a 16.75% potential roof area for collecting solar power for detached houses.

A rough amount of roof area for detached houses in Uusimaa is 28 555 576 m^2 (Statistics Finland 2014). Even though this data is for floor area we can assume that it is very roughly the same amount as the roof area:

28 555 567 $m^2 \times 0.1675 =$ 4 783 058 m^2 this area is the hypothetical area that could be used for solar panels. This does not necessarily mean they have to be installed on the roofs they can be also installed on the ground.

As mentioned before the average household (120 m^2) uses about 18480 kWh per year. The area needed for the sun panels to produce 100 % of the electricity with an average sunlight of 5 hours would be 52 panels which would take up an area of 75.8 m^2 with standard solar panels. The ratio of the area that would be required for the solar panels is:

(75.8 / 120) $m^2 = 0.632$

When multiplying this ratio with the total area of 1 floored detached houses the result is:

4 783 058 $m^2 \times 0.632 =$ 3 022 893 m^2.

This value can then be used in the PV calculator (see below). When putting this value also a value of the annual irradiation is required and that can be obtained by using the annual irradiation map (see below). The panel efficiency is 15 %. The total power of the system is then calculated and in the case of Uusimaa the total power is 453.4338 MW_p, which means that the system has a capacity of 453 MW when the performance is ideal.

3.3 Potential solar power in Finland regionally

It can be seen from the figure 4 below the potential that each region can produce. As is shown Uusimaa has the potential to produce 2.90 PJ, 158 375.9 tons of coal would be saved and an equivalent of 43 606 households would benefit from the solar power. The rest of the values and calculations are shown in the appendix 3.

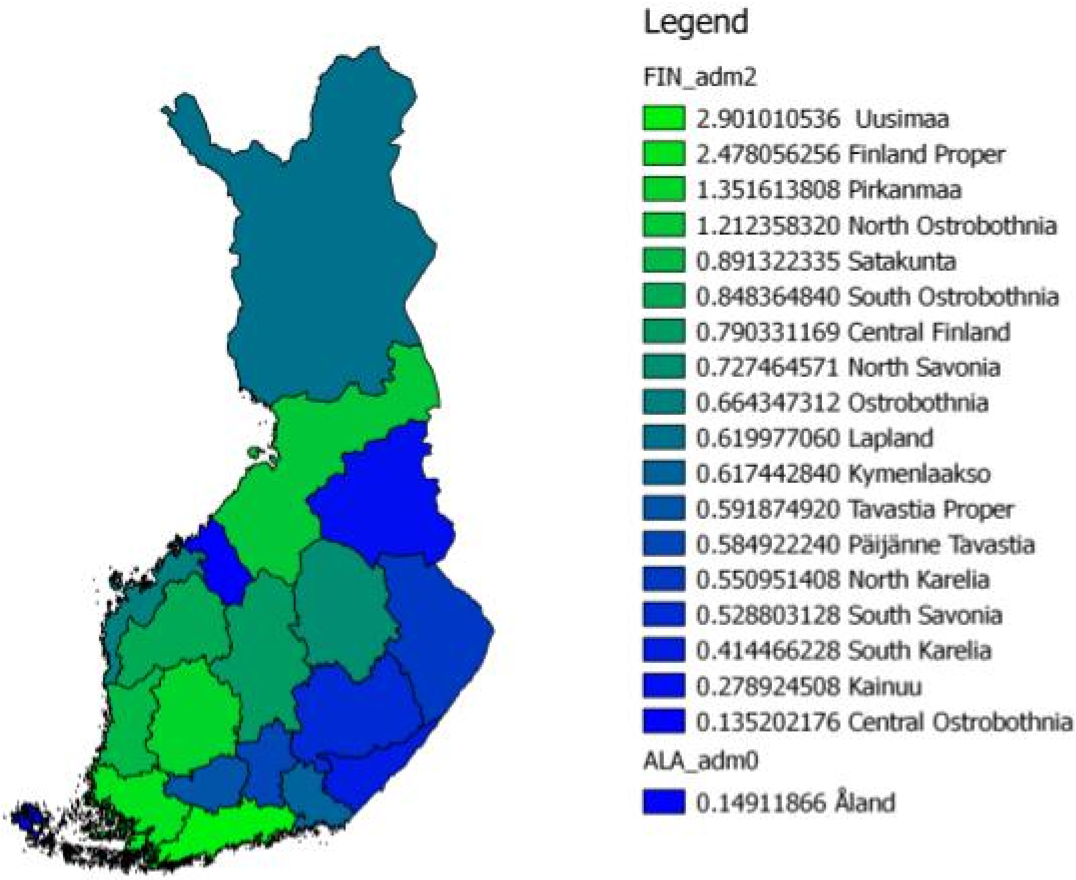

Figure 4. The total energy that each region can produce in PJ.

4 Potential Bioenergy Production Regionally

Biofuels are widely used in Finland especially from the forestry industry; this makes it one of the leading countries that use biomass as a form of energy. The share of bioenergy is roughly 20 % of all primary energy consumption and ranks it the second highest in the EU after Latvia. Finland has a long tradition of a highly developed wood and paper industry due to its extensive forest which 68 % of the forest consists of boreal coniferous (Renewable energy in Finland 2015).

In recent years the wood and paper industry has been declining throughout the past years and this seems to continue. It has been forecasted that the paper and the pulp industry will decrease by a third and the wood processing production by just a fifth from 2007 to 2020. This is due mainly to Finland's position in exporting, as demand has decreased and other competitors are decreasing Finland's export competitiveness. There are three factors for decrease in export. First the world's economy is in a stagnated state which has affected on the demand and the prices of the pulp and paper products. Secondly the structured change of how we use paper is changing as the demand for paper is decreasing and being replaced by an electronic medium. Thirdly Asia's entry into the market has also increased the supply of paper into the Western market raising the competiveness and lowering the prices. Also this trend can be seen in the saw wood market as it is becoming increasingly harder for Finland to export wood with competition from Sweden and Russia (Hetemäki, Hänninen 2008).

Finland is one of the world leaders in the use of combined heat and power (CHP) plants and biomass is used as a fuel in the boilers mixed with other fuels such as peat. The world's largest bio power plant with a capacity of 265 MW is situated in Pietarsaari in Finland. The power station uses wood-based biofuels as the main fuel; peat is also used while coal is a reserve fuel. The power station provides the local city Jakobstad with 60 MW of district heating in addition to electricity and a 100 MW process steam and heat for the UPM-Kymmeen paper mill (Alholmens Kraft Power Station 2015).

For direct space heating in remote areas that are not connected to district heating, wood is used to heat the spaces. In total around 6 million m^3 or 50 PJ of fire wood are used annually. The new technologies consist of burning pellets in dedicated boilers, also fuel oil fired heating can be converted to use pellets, which has been estimated to have a potential of 25 PJ/annum.

As mentioned above the forest industry provides a sizable amount of wood biomass that is used directly or indirectly in production of energy that totaled about 20 % of Finland's total energy consumption which translates to about 70 TWh/annum. The by products are bark, sawdust and black liquor as by products from pulp-making process. About 40 % of the raw material wood brought into the pulp and paper mills ends up being used to produce energy at some phase of the production process. The branches, crowns and stumps of harvested trees cannot be used by industry to produce timber goods or pulp and paper. But they can be chipped to make wood-chip fuels that can then be used to generate carbon-neutral bioenergy (Forest biomass for energy 2004).

The use of wood-chips to create energy in Finland has eight folded since 2000. Approximately 7.5 million cubic meters of wood-chips were used to generate bioenergy in Finland in 2011. Most of this volume (6.8 million m^3) was used in heating and power plants. They are not only restricted in the usage of power plants, they can also be used in large complexes as in heating large industrial halls, in the farming complexes, in heating the built up areas and in the city district heating plants. The figure below shows the forecast in the coming years until 2020. If the predictions are right then by 2020 Finland will be using approximately 13.8 million m^3 of biomass for energy production (Somerpalo Jussi 2004).

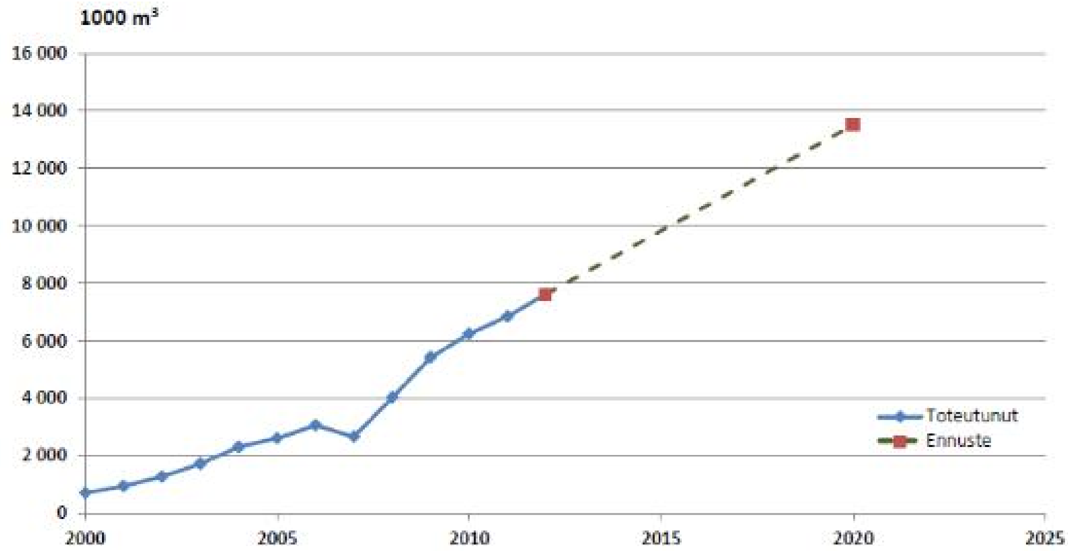

Figure 5. The forecast of wood production in the coming years from the forest industry (the blue line is what has been achieved and the green dotted line is the forecast until 2020).

4.1 Potential bioenergy region wise

The figure below shows the amount of potential energy that can be produce by region. As can be seen the highest values are obtained from Central Finland with 9.2 PJ production annually and Åland the lowest with 0.02 PJ annually. The total for all of Finland is about 88.209 PJ.

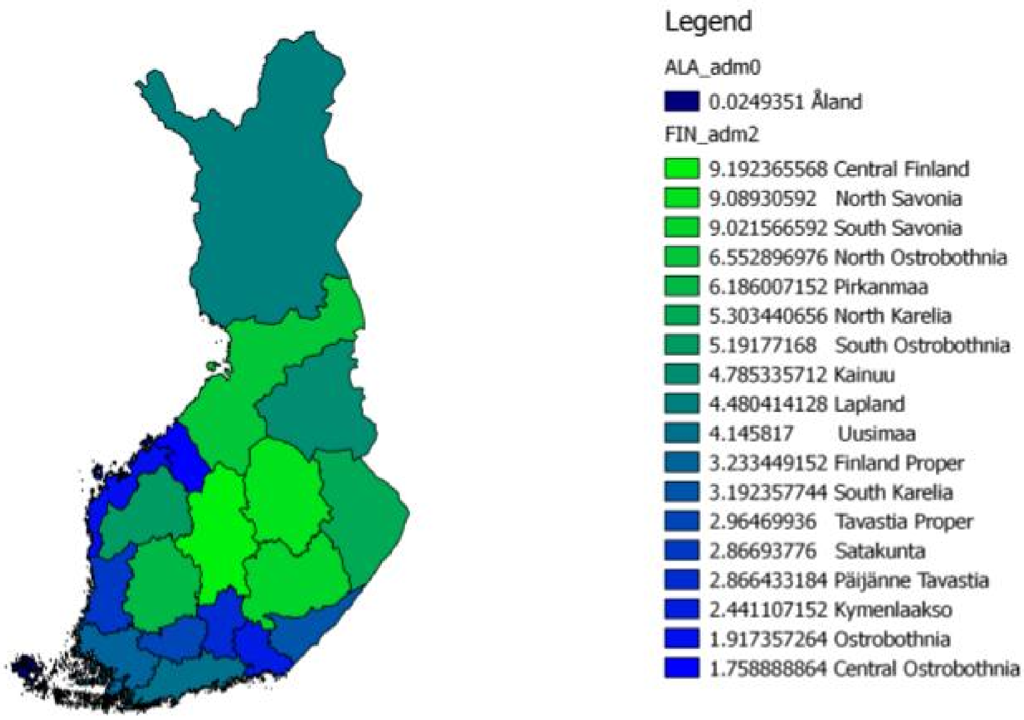

Figure 6. Potential energy from wood biomass by region in PJ per annum.

The values are obtained by using data that are technically possible when gathering wood biomass from the industry and the fields (see appendix 4). In the research what was taken into consideration is the technical aspect of gathering the wood biomass. Wood biomass is composed of needles, branches, sawed off canopies, stumps and the roots. Also in farming trees biomass can be collected from trimming the trees that are not suitable or are not qualified according to standard measurements.

The research was based on looking at what is potentially technically possible in gathering the wood biomass. The areas that are left out are unsuitable areas such as for environmental/eco-biological reasons and areas where the collection of the biomass would be unfeasible. Also it is not possible to collect the entire residue because of machinery restrictions and logistics.

The technical potential of gathering wood biomass can change easily with what happens in the forestry industry. One change can be the improvement of the collection machinery and new innovations. Another aspect is the price market and the cost of collecting the biomass. The changes in the market can have many aspects such as: the price of fuel, international and local legislations on energy and as mentioned previously the overall paper and forest industry also have an effect. Another consideration was taken into account was the willingness of landowners and farmers to sell their wood and their attitude towards gathering and using wood as an alternative energy source. This was done by doing a survey with landowners. In Finland there are 5000 landowners who pay the required forest maintenance tax (2001) from these 2 131 answered the surveyed questions. The results are: southern Finland 68 % would be willing to sell their lumber for energy use, western Finland 65 %, east Finland 65 %, Oulu region 65 % and Lapland 67 %.

5 Geothermal Heat Pumps

The utilization of large scale geothermal power plants such as the likes in Iceland is not possible in Finland due to its geological characteristic. Finland belongs to the Fennoscandian shield, the bed rock is Precambrian covered with a thin layer of less than 5 m of Quaternary sediments. Topography is subdued and does not easily produce adventive re-distribution of geothermal heat by groundwater circulation systems. This is because the structure of the bedrock is crystalline which lacks porosity that leads to low content of underground water in the rocks. This practically excludes geothermal systems utilizing hot wet rock (Kukkonen Ilmo 2000).

Geothermal gradient is typically 8-15 K per km and the annual average of the ground at the surface ranges from about 5 ^{o}C in the south to about 2 ^{o}C in the northern parts of the country. Temperatures at 500 m below the surface are usually between 8 and 14 ^{o}C. At 100 m the temperatures ranges from 14 to 22 ^{o}C. To reach 100 ^{o}C temperatures it would be required to go to depths of 6 to 8 km. So to have a large scale geothermal plant would be a challenge but this does not exclude the possibility of using geothermal heat pumps (Kukkonen Ilmo 2000).

The annual average temperatures in the soil at the depths of 1 m vary between +2 to 12 ^{o}C in southern Finland and in the northern parts of Finland -2 to + 12 ^{o}C. The annual temperature below 1 m to 200 m varies from +2 to +8 ^{o}C. These kinds of temperatures are useful when used in small scale such as small family houses, country farms or small scale district heating communities. This heat can be extracted by using heat pumps that are installed with horizontal or vertically in boreholes in Quaternary sediments. Also lakes and rivers can be used for the same purpose. These heat sources are extracted from the surface as a result of geothermal energy and solar energy that heat up the layers of the earth (Kukkonen Ilmo 2000).

Due to the restriction of the geology of Finland, small scale heat pumps are the most common way to utilize the heat from the ground. The average households in Finland use about 13,200 kWh per year of energy for heating space and domestic hot water. Depending on the type and size of the property a vertical or a horizontal installation can be used. The required capacity of a heat pump is usually about 8-9 kW which is about 60 % of the required heating power. This is due to the fact that the duration of the extremely cold weather only last few weeks per year and recently not even that in the southern parts of Finland. So the heat pumps satisfy about 90 % of the annual demand of heating energy, when more energy is required, then it can be supplied by electricity from the power plants (Kukkonen Ilmo 2000).

The vertical grounded coupled heat pumps are typically installed in boreholes 80-130 m deep. Energy is extracted about 40-60 W/m borehole. An ethanol-water solution is used as the heat exchange fluid and it is circulated in a U-shaped plastic installed in the borehole. The horizontal ground coupled system use pipes that are buried about 1-1.5 m. In the typical installation for a 130-150 m^2 family house the total length of the pipes is about 150-130 m. Horizontal coupled systems in lakes or rivers usually dimensioned with slightly shorter pipes than those in sediments (Kukkonen Ilmo 2000).

In a news article by SULPU there are already 540,000 heat pumps that are in use which take energy from the ground, water, and air. In 2012 the amount of ground heat pumps sold was 13 000 units, which was 7 % less than the previous year, although the sale for larger scale ground heat pumps increased for apartments and row houses by 30 %. These are still good results, since in 2011 the growth of sales of heat pumps was 72 %. A growing trend in installing heat pumps is in the sector of oil heating row houses and apartments, which has an increase of 1000 heat pumps installment per year. New small scale houses that are being built more than half are installing heat pumps. The biggest potential is of course the houses that have been built already. Houses that have oil based heating systems which range in the number of 220 000, over 100 000 houses that use electrically heated cyclic water and houses that use direct electrical heating which range in 500 000. By investing in heat pumps the customer will reduce in electrical bills at least by half (SULPU 2015).

The heat pump mark is on a thresh hold now depending on the economy and the price of primary fossil fuels. It has advanced dramatically in recent years and it has been predicted that it will great revenue of 800 million euros by 2020 if 1 million heat pumps are installed, which adds up to 8 TWh/a. This will save Finland from releasing 1 billion ton of carbon dioxide into the atmosphere a part of the agreement that Finland had signed with its EU partners in cutting down on greenhouse gasses (SULPU 2015).

5.1 Total potential of geothermal heat pumps regionally

The figure below shows how much energy each region has the potential to produce from installing geothermal heat pumps. It does not take into account already installed heat pumps since it is hard to obtain exact data on how many heat pumps have been installed in the previous years. The calculations are based on how many households are in each region and a hypothetical estimate of an increase of heat pumps of 1 per cent each year until 2020. In the appendix 5 the table shows the total energy, tons of oil equivalent (TOE) and households that each region has the potential of producing with an increase of 6 per cent of heat pumps by 2020. For example Uusimaa has the potential of 0.35 PJ and would save the use of 10 089 TOE. This amounts to supplying energy for a year to 5 291 households that use on average 18 480 kWh per year.

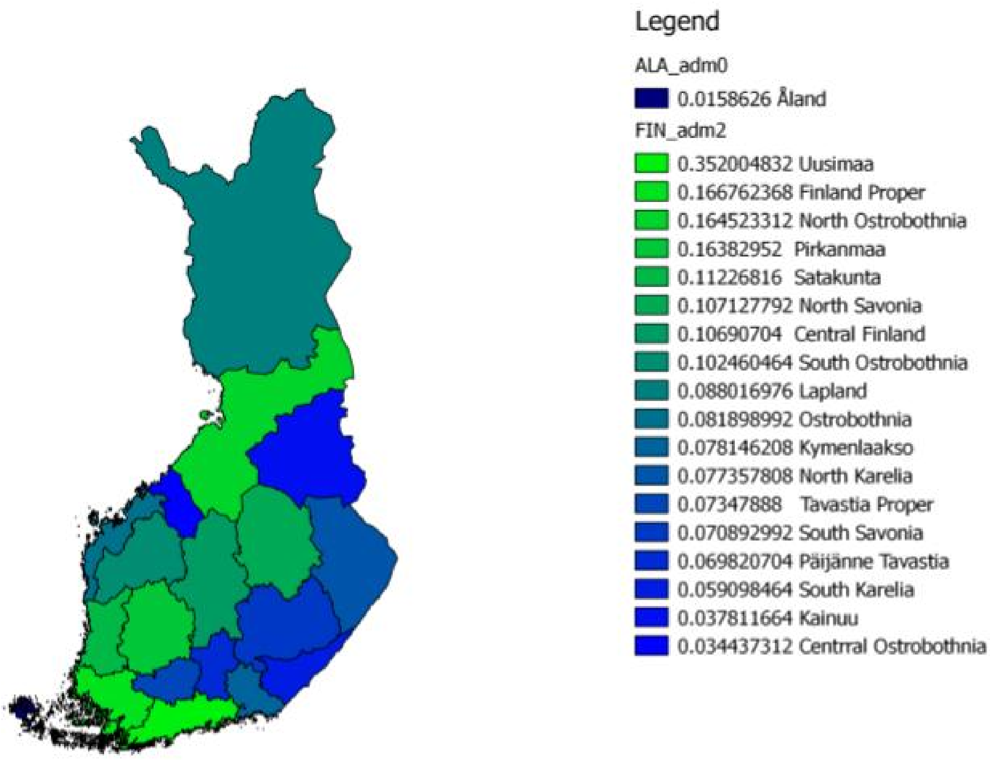

Figure 7. The total energy of geothermal energy from heat pumps in PJ for each region.

6 Hydropower

The second largest source of renewable energy in Finland is hydropower after bioenergy. In the beginning Finland built its hydro plants for mechanical reasons such as to turn the saw mills and grain mills. As electricity started to become more common so was the transition from mechanical to electrical production. Imatrankosken hydropower plant became active in 1928 and it had a capacity of 178 MW which was until 2011 the largest in Finland. It was surpassed by Petäjäskoski with a capacity of 182 MW when its capacity was upgraded. Imatrankosken third turbine had also an upgrade in 2014 which raised its capacity to 185 MW which made it the highest and making it yet again Finland's largest hydro plant (Vesivoimalat Suomessa 2015).

Currently Finland has 7 hydropower plants that are over the 100 MW capacity. There are 30 hydropower plants which are classified as medium size (20-100 MW) and 37 small sized power plants that are under 20 MW. Their combined capacity is 2632.05 MW. Comparing the capacity of hydropower to the combined capacity of power stations in Finland in 2009 (12.9 GW) is 20.4 %. In another survey done by the Commerce – Industry minister in 2005 showed that Finland total potential for hydropower was about 5 100 MW which is about 22.6TWh of energy production per year. From this amount 3 050 MW is already built which corresponds to a yearly production of 13 TWh (Vesivoimalat Suomessa 2015).

6.1 Potential hydropower

Finland's major potential hydropower stations are situated in protected natural areas or in areas on the border with Russia. In other areas the potential is less than half of the mentioned above and energy wise is only 30 % of the energy of protected natural areas (OY Vesirakentaja, 2008, Voimaa Vedestä 2007).

Finland has somewhat the potential to increase its capacity without interfering with the protected natural areas. The estimates are that an addition of 175 MW can be built by the year 2010 and 235 MW by the year 2015. In the year 2020 there is potential to increase the capacity from the previous estimates by 60 MW. From the total by 2020 a quarter of the increase in capacity is due to improvements to the already existing hydro plant’s machinery. The most important new hydro plants can be built in the areas of Kemijoki, Iijoki and Kymijoki where over half of hydropower capacity is situated in Finland. In addition to the above there is potential to build an addition of 460 MW of power in the areas of Ounasjoki and Iijoki downstream midsections which converted would produce 1.6 TWh/annum of energy. Both river areas are protected natural reserves (OY Vesirakentaja, 2008, Voimaa Vedestä 2007).

Over 100 MW of potential capacity will be left out of the frame work due to financial and environmental reasons. The current hydropower plants can be upgraded for better efficiency only in situations when the plant is going through renovations. This can be speeded up by the help of governmental incentives (OY Vesirakentaja, 2008, Voimaa Vedestä 2007).

If these potentials mentioned above were to take place they could reduce the consumption of coal by 383 000 – 822 000t this would be the same amount that would be burned in the production of electricity using coal or natural gas. Also with hydropower the reduction of other harmful pollutants can be reduced and the reduction of disposable waste. Building hydropower plants also produce some waste but they can be managed and mitigated through strict regulations and environmental audits, and if regulations are broken then the participants have to pay compensation in money. In Finland the cooperation with the local municipality and the local residents has improved to a degree in reducing the amount of pollution that a hydropower plant might cause (OY Vesirakentaja, 2008, Voimaa Vedestä 2007).

6.2 Potential hydropower regionally

The figure below shows the total energy that each region has the potential of producing with current hydro plants in PJ. As is shown in the figure below Lapland can produce 38.51 PJ of energy. That is equivalent to 2 102 486 TOC and can provide energy to 57 8881 average household. The rest of the values are demonstrated in the appendix 6.

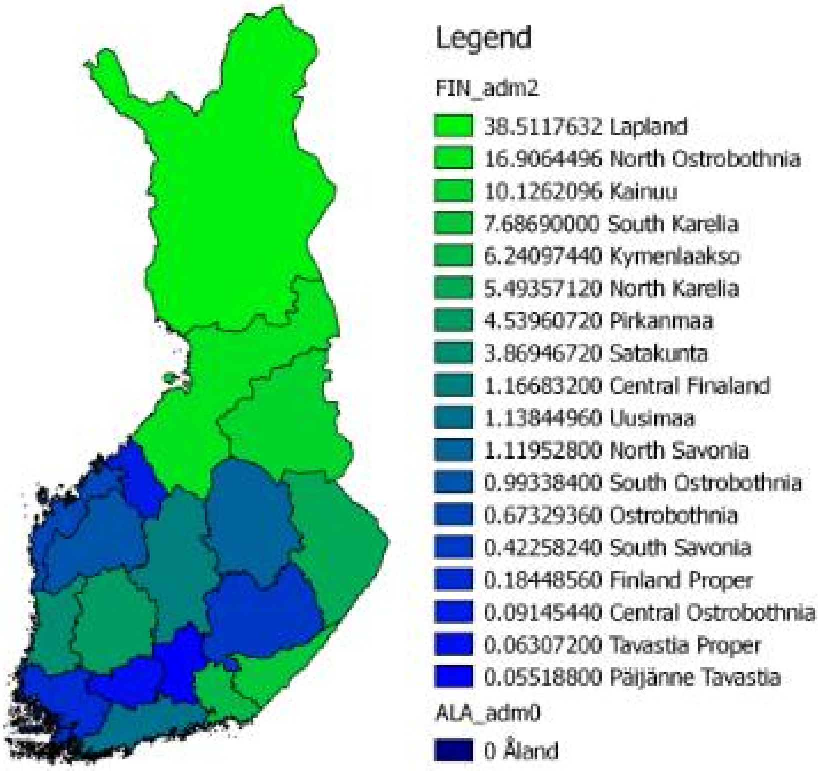

Figure 8. Total hydropower by region in PJ.

The figure above shows the total energy that each region has the potential of producing with current hydro plants in PJ. As is shown in the figure above Lapland can produce 38.51 PJ of energy. That is equivalent to 2 102 486 TOC and can provide energy to 57 8881 average household.

7 Small scale untapped hydropower

In 2010, Finland had 152 small plants divided into 73 plants with 1-10 MW and 79 plants with less than 1 MW. The total installed capacity was 302 MW. In addition to these plants, there are approximately 40-50 plants with a capacity of less than 50 kW (micro-hydro), operated without connection to the national grid. By 2020 the aim is to have 160 plants with a total installed capacity of 305 MW (generating 1,330 GWh).

The feasibility of mini hydro plants needs to have some criteria before they can be considered to be productive (Pienvesivoimakartoitus 2007);

- Refurbishment of existing hydropower plants is assumed to have equal feasibility for plants larger than 0.1 MW. The benefits of refurbishment are evaluated with 5-15%, depending on the mean base-condition of the different sectors.

- Mini-hydropower plants that are larger than 0.5 MW are considered to be feasible to be constructed.

- Mini-hydro plants that are out of use but have an intact structure but the equipment are out of order, and then it is feasible for refurbishment only if the capacity is at minimum 0.1 MW.

- Any site that has less than 0.1 MW is considered not feasible to be constructed, even if the site has old mills or out of use hydropower plants. Nonetheless these sites are taken into consideration as non-feasible sites and incorporated into the calculations of potential mini hydropower (Pienvesivoimakartoitus 2007).

The table 1 below shows the potential of mini-hydropower potentials mean values.

Table 1 Small scale hydropower < 1 MW (Pienvesivoimakartoitus, Minivesivoimasektori < 1 MW)

Hydropower potential Mini-hydro, less 1MW	Non-protected	Environmentally protected	Together
POWER (MW)	144	148	292
ENERGY (GWh/a)	1021	916	1937

The values presented above are a potential of numerous scenarios of mini-hydropower plants between non-protected and environmentally protected areas. As can be seen the non-protected accumulate 144 MW of power (1021 GWh/a) and the environmentally protected accumulate 148 MW (916 GWh/a) of potential power.

Based on optimistic and realistic assumptions the values are different than the values presented above. Also taken into consideration is the feasibility of the potentials of investing into mini-hydropower plants. The values can be seen below in the table 2.

Table 2. Small scale hydropower < 1 MW (Pienvesivoimakartoitus, Minivesivoimasektori < 1 MW)

Hydropower potential, mini-hydro, less 1MW	Non-protected				*) Environmentally protected	Together
	Highly feasible	Less feasible	Not feasible	Together		
POWER max (MW)	130	73	34	237	177	414
POWER min (MW)	107	60	30	197	177	344
ENERGY max (GWh/a)	671	298	156	1125	830	1955
ENERGY min (GWh/a)	487	197	120	804	830	1634

*) Only one prediction has been prepared for the environmentally protected potential

The table 2 above shows that highly feasible potential in the range of maximum power is 130 MW producing 671 GWh/a, annual production of 5 162h. The minimum is 107 MW converted to energy is 486 GWh/a, annual production of 4 551h. Less feasible maximum power is 73 MW and converted to energy 298 GWh/a, of an annual production of 4 082h. The minimum for less feasible power is 60 MW translates to 197 GWh/a, of an annual production of 3283h. Not feasible power generation is 34 MW converted to energy is 156 GWh/a, annual production of 4 588h. The minimum power is 30 MW converted to energy is equal to 120 GWh/a, annual production of 3 922 h. The total maximum power is 237 MW translates to 1 125 GWh/a, annually the production of 4 747h. The total minimum power is 197 MW, annual energy production of 804 GWh/a, and total hours of running time 4 081h. The environmentally protected rivers only had one prediction to all scenarios of 177 MW and 839 GWh/a of energy and total hours of generation 4 689h. Adding the values together the total maximum power is 414 MW and total energy 1955 GWh/a with production time of 4 722 h. The total minimum power is 344 MW and total minimum energy of 1634 GWh/a, calculated hours of production 4 750h.

The table 3 below shows the development of the increase of 130 MW or 671 GWh/a in four stages within 15 years in 5 year intervals. The table 3 illustrates a realistic approach to the development of mini-hydro plants from 2005 to 2020.

Table 3. Small scale hydropower < 1 MW (Pienvesivoimakartoitus, Minivesivoimasektori < 1 MW)

Year	POWER PREDICTION (MW)				ENERGY PREDICTION (GWh/a)			
	Currently installed power	Taking into operation an increase in power potential		Installed power available	Current Energy production	Predicted energy production accordingly to increase in power		Energy available
		%	MW	MW		%	GWh/a	GWh/a
2005	57.2	0	0	57.2	247	0	0	247
2010	57.2	27.3	35.5	92.5	247	26.3	177	424
2015	57.2	54.3	70.7	127.7	247	52.4	352	599
2020	57.2	81.2	105.7	162.7	247	78.6	527	774
2020 not in use	57.2	18.8	24.3 MW		247	21.4	144GWh/a	
>2020*	57.2	93%-100%	122-130	179min 187max	247	83%-100%	555-671	802 min 918 max

*) remaining share of hydropower potential to be developed or remaining undeveloped after the year 2020

In the year 2010 an increase of 27.3 % of 130 MW's would be 35.5 MW's, added to the current installed power of 57.2 MW the installed power available would be 92.7 MW's. In 2015 the increase in power is 54.3 % which is an increase of 27 % from the previous 5 years. That translated to power from 130 MW's is 70.7 MW's, added to the currently installed power of 57.2 MW's the installed power increase is 127.9 MW's. In 2020 the increase of 27 % to the previous installment is 81.3 %. 81.3 % from 130 MW's is 105.7 MW's an increase to 162.9 MW's from the previous interval. In the less feasible potential of power 73 MW's and energy production of 298 GWh/annum could possibly be developed up to 50 % of this potential until the end of the year 2020.

The table below is a summary of the realistic values that describe an increase of potential by an interval of five years starting form 2005 till 2020 (107 MW's and 487 GWh/a). As the calculations where done in the same method as above but with the realistic initial value of 107 MW's. Also the less feasible potential power of 60 MW's is taken into consideration and could see an increase of potential power up to 40 % until the year 2020.

Table 4. Small scale hydropower (Pienvesivoimakartoitus, Minivesivoimasektori < 1 MW)

Year	POWER PREDICTION (MW)				ENERGY PREDICTION (GWh/a)			
	Currently installed power	Taking into operation an increase in power potential		Installed power available	Current Energy production	Predicted energy production accordingly to increase in power		Energy available
		%	MW	MW		%	GWh/a	GWh/a
2005	57.2	0	0	57.2	247	0	0	247
2010	57.2	12	12.9	69.9	247	11	52.8	300
2015	57.2	41	43.4	100.4	247	39	190.1	437
2020	57.2	64	68.1	125.1	247	62	300.8	547
2020 not in use	57.2	36	39 MW		247	38	185GWh/a	
>2020*	57.2	80%-100%	86-107MW	143 min 164 max	247	79%-100%	383-487GWh/a	630 min 734 max

*) remaining share of hydropower potential to be developed or remaining undeveloped after the year 2020

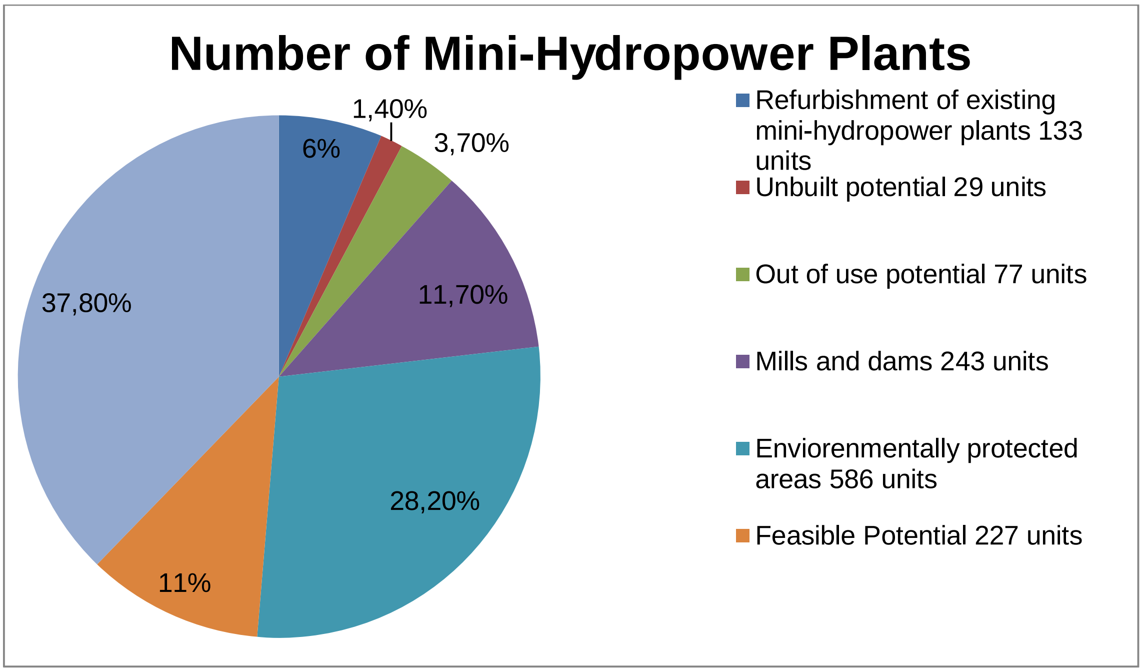

Figure 9. Small scale hydropower (Pienvesivoimakartoitus, Minivesivoimasektori < 1MW)

The table 4 above represents the number of mini-hydropower plants in Finland, the realistic and the optimistic potential. From those there are 133 mini-hydropower plants that have the potential of an increase in power after refurbishment. There are 29 mini-hydropower plants that have the potential to be built. There are 77 mini-hydropower plants that are out of commission. 243 mini-hydropower plants can be potentially installed in mills and artificial dams. Environmentally protected areas have a potential to install 586 units.

The feasible potential to install mini-hydropower plants is 227 units. The majority of mini-hydropower plants that is not worth installing are 786 units. A total 2081 mini-hydropower plants.

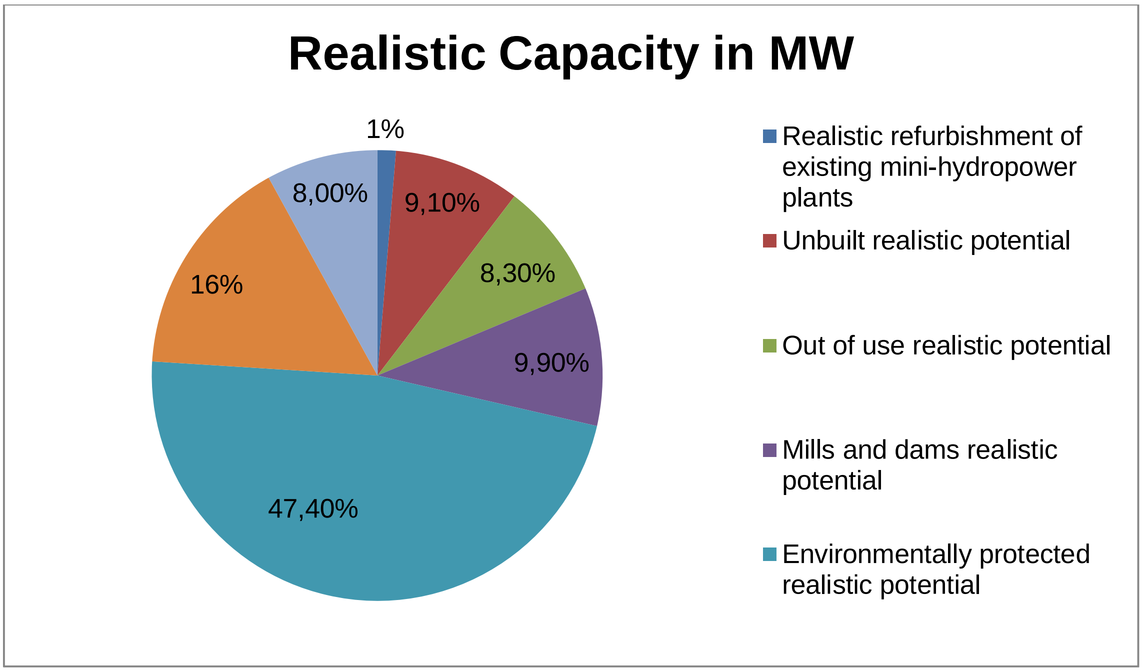

Figure 10. Small scale hydropower (Pienvesivoimakartoitus, Minivesivoimasektori < 1MW)

The table above represents the realistic potential that the mini-hydropower plants have the potential of producing in MW. The realistic potential of existing min-hydro plants is 4.8 MW, in percentage is 1.3%. The potential for construction of new plants is 132.6 MW a 9.10%. Out of use potential is 110.1 MW. Construction of mini-hydropower plants on existing mills and dams has a potential to produce 223.3 MW. Environmentally protected areas have a potential of 177.2 MW. Realistically feasible power plants have a potential of 59.6 MW and the not feasible have a capacity of 30 MW.

This is a total of 373.6 MW of capacity. Keeping in mind that most of this capacity cannot be used or is not feasible, and then the total is reduced to 135.4 MW a 36.2% of the total capacity. In the table below the realistic amount of energy that can be produced is shown in GWh/a.

From a survey done to hydropower plants owners in the country, it was possible to acquire information about the power plant and its future plans on production of energy and efficiency. The survey shed a light on the amount of power plants that are in use (221), where their combined power is about 3000 MW and an annual production of energy 13 TWh. Finland has untapped potential of 2130 MW, which can be converted to 9715 GWh/a, from this total a 663 MW of useable potential energy of 2352 GWh/a that is not protected. Subtracting the non-feasible potential such as to small hydropower or too remote hydropower then the figure is reduced to 580 MW and annual energy of 986 GWh/a. Mostly of the increase of potential will be done on already existing power plants by raising the efficiency of the machinery by the year 2015. After that the potential will increase slightly depending on water regulations and environmental regulations.

7.1 Regional potential hydropower

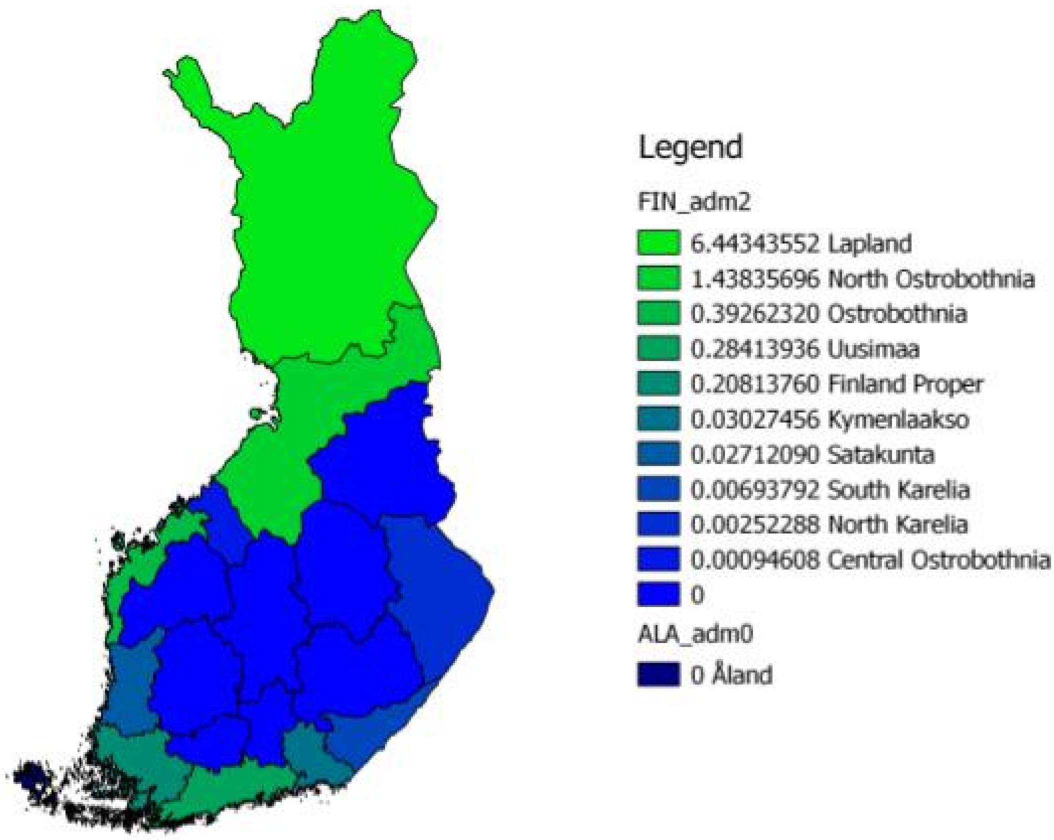

Figure 12. Potential small hydropower by region in PJ.

The map above represents the potential energy of hydropower plants in Finland for each region in PJ. The power plants that are counted as potential energy are mini-hydropower plants (<1 MW), small power plants (<10 MW) and large scale hydro plants (>10 MW). It should be noted that Finland has built the majority of the hydropower that are feasible to build. Also many hydropower plants that can be potentially constructed are in areas that are protected from such constructions. The handful of hydropower plants that can be built are limited. The majority of the feasible hydropower plants are ones that are being renovated or the machinery is being replaced with more modern and higher capacity machinery that raise the capacity of the power plant. The map above represents an overall view of hydro plants regardless of if they are feasible or not. The locations of the power plants on the map were determined by comparing the data of the hydropower plants that exist in “Hydropower plant in Finland” (see appendix 7 table 14) and the ones mentioned in the inventory (see appendix 7 table 14). The map represents the potential theoretical hydropower and not the realistic potential power. In the map it is shown that the potential hydropower is situated around the coast of Finland, where central of Finland seems to lack potential, but this can be misleading. The potential can be raised by installing more efficient turbines and generators. These values are not included in the map. From the map it can be seen that the largest potential is produced in Lapland (6.443 PJ), but most of the potential cannot be used due to the remoteness or non-feasibility.

8 Total Potential and Distribution

Since Finland is part of the EU it has signed to an agreement that the commission has drawn up that requires 20 percent of the energy consumed within the European Union is renewable. Finland was obliged to report how Finland planned to achieve its legally binding target of a 38% share of energy from renewable sources in gross final consumption of energy by 2020. The main outlines of the approach is the use of renewable energy are set out in the Long-term Climate and Energy Strategy submitted as a report to the Finnish Parliament in November 2008 (VNS 6/2008 vp). It is estimated that by 2020 renewable energy sources yielding 77 TWh will be subject of policy measures as against 37 TWh in 2005. Final energy consumption in 2020 is estimated at 327 TWh for the whole nation. The main incentives and laws in Finland are: wind power, wood chips and other energy from wood, hydro power, small scale use of wood, heat pumps, transportation biofuels, biogas, pellets, recycled fuels and solar energy (Renewable Directive).
The thesis looks into some of the incentives mentioned above and it is fitting to do a comparison with the predictions that the Climate and Energy Strategy (CES) have made and the results that the thesis got.
Wind power production is predicted to rise to 6 TWh by 2020 according to CES. The mapping and calculations made in the section of wind power in the thesis shows that the total energy for Finland is about 73.790 PJ, converted to TWh is about 20.5 TWh in theory. 6 TWh is 29.3% of the total (20.5 TWh). In theory this does look promising and

an achievable goal to have an increase of 30% wind production (Finland National Renewable Energy Action Plan).

The use of wood chips in combined heat and power plants and separate production will be increased to 12 million m^3 by 2020, an estimate by the CES. A rough estimate of the energy produced is 24.84 TWh if the average of energy per m^3 is 2.07 MWh/m^3 as mentioned in the section of bioenergy. The total calculated energy in the thesis is about 24.503 TWh. This is close to the estimated value of CES. There is an incentive to increase the use of wood chips in a three part aid package devised to increase the competitiveness of forestry energy to a level at which the required growth can happen. The support package to be presented comprises energy support for small-sized wood, a feed-in tariff to compensate for the difference in costs between wood chips and alternative fuels, and a feed-in tariff for small CHP plants (Finland National Renewable Energy Action Plan).

Hydro power production is to be increased by around 0.5 TWh per year of average water flow, to 14 TWh in 2020. The Ministry of Employment and the Economy is drafting an amendment to the guidelines for granting support which will make it possible to grant support for plants of up to 10 MW, rather than the current maximum of 1 MW. Just inspecting the data from untapped potential hydro power the total amount of energy production is 8.8335 PJ which is about 2.454 TWh. This falls short from the 14 TWh. The large difference is due to the fact that in the mapping phase it was not taken into consideration the improvement of power production on existing hydro power plants be it small or large plants (Finland National Renewable Energy Action Plan).

In the case of geothermal heat pumps the plan is to raise the production of energy to 8 TWh by 2020. Measures that are to be implemented are that renovated houses for energy efficiency, heat pumps will be taken into the calculation of the overall energy usage of the house that is being renovated. The total energy that is calculated in the section of geothermal heat pumps is 1.9628 PJ an equivalent of 0.541 TWh. This value is only 6.8% of the value given in the CES plan. Since CES has not published their method of calculation and scheme to reach the 8 TWh it was not possible to do a comparison with the values in the thesis to the value calculated in the CES plan (Finland National Renewable Energy Action Plan).

The CES plan for solar power and solar heating will continue in the same manner that it is currently with the aid of energy subsidies. Solar heating systems are promoted through the tax system by granting a carbon offset to single households that install solar heaters. The total energy represented in the thesis for solar power is 16.1874 PJ converted TWh is 4.4965 TWh. This value is an estimate and further research is needed to see if this is possible and realistic (Finland National Renewable Energy Action Plan).

8.1 Total potential of renewable energies

The goal of this thesis is to investigate the potential of Finland's power and its distribution in the sector of renewable energy, and then to have the findings mapped as to see which regions have the most potential to produce energy other than conventional methods. The figure 13 below shows the total power production from wind, bio, solar, geothermal and hydropower combined in PJ. The total potential renewable energy is 292.062 PJ converted to TWh is equal to 81.128 TWh. The bulk of the renewable energy comes from bioenergy, hydropower and wind power.

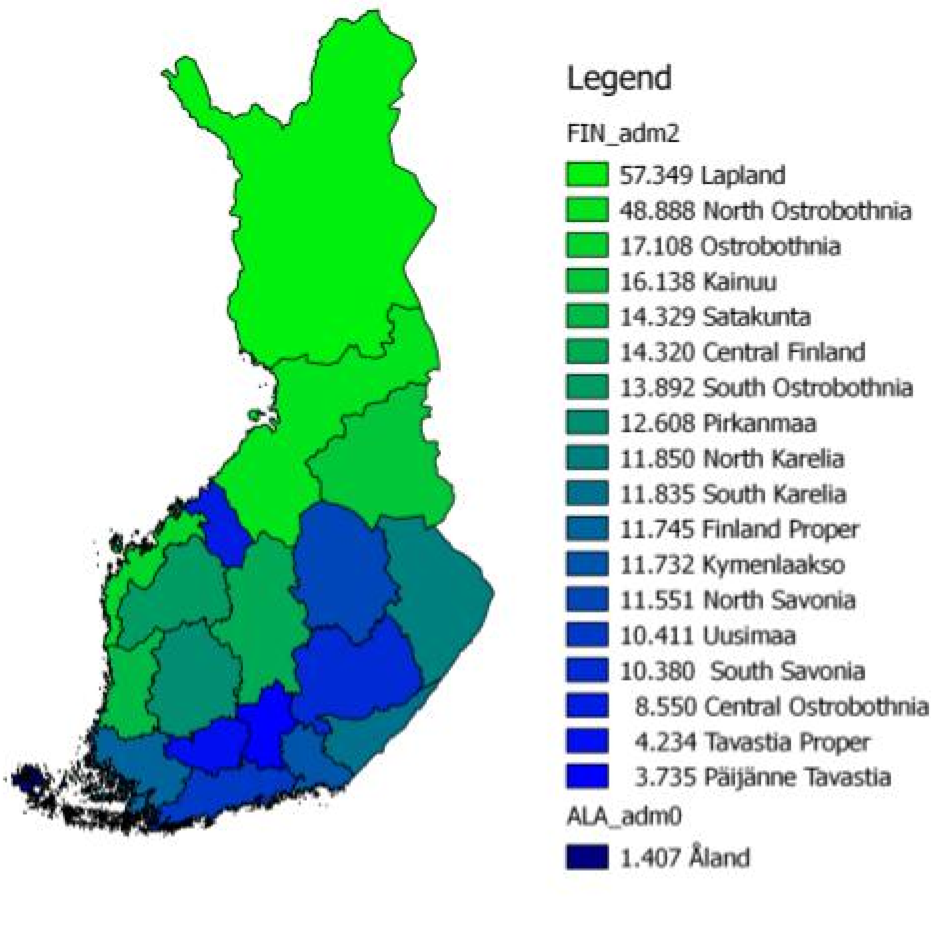

Figure 13. Total potential renewable energy in PJ.

In the attribute Table 5 below the energy is converted to represent the energy in different forms; in PJ, tons of coal equivalent (TCE), tons of oil equivalent (TOE) and households (Hh's). The idea of converting PJ to other forms of energy units is so that the reader has an idea of what quantities of energy is represented in each region. It also illustrates a rough estimate on the amount of coal and oil that would be saved from going into the furnace. The values in TOE represent the equivalent values of geothermal heat pumps since some households use oil based fuels, and then it is appropriate to represent the energy from heat pumps into TOE. The data under the units Hh's is meant to represent a quantitative number in comparison to a large number such as PJ's. So as the reader can compare the amount of energy each region has the potential of producing.

Table 5 Total potential renewable energy in PJ, TCE, TOE and Hh's by region.

NAME_2	VARNAME_2	Energy_PJ	Energy_TCE	Energy_TOE	Energy_Hhs
Lapland	Lappi|Lappland	57.349	3131838.930	3363.599	862001
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	48.888	2531796.500	4715.486	736512
Ostrobothnia	Österbotten|Pohjanmaa	17.108	929463.863	2347.349	257140
Kainuu	Kainuu|Kajanaland	16.138	781054.391	1084.739	24250
Satakunta	Satakunta|Satakunda	14.329	776189.049	3217.775	215397
Central Finland	Keski-Suomi|Mellersta Finland	14.320	464965.622	3064.117	215248
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	13.892	752881.632	2936.671	208832
Pirkanmaa	Pirkanmaa|Birkaland	12.608	679383.018	4695.601	189518
North Karelia	Pohjois-Karjala|Norra Karelen	11.850	642655.738	2217.191	178105
South Karelia	Etelä-Karjala|Södra Karelen	11.835	642883.765	1693.851	177893
Finland Proper	Varsinais-Suomi|Egentliga Finland	11.745	620813.396	4779.661	176564
Kymenlaakso	Kymenlaakso|Kymmenedalen	11.732	522037.259	2239.788	176370
North Savonia	Pohjois-Savo|Norra Savolax	11.551	624760.747	3064.117	173626
Uusimaa	Uusimaa| Nyland	10.411	549242.709	10088.989	155795
Southern Savonia	Etelä-Savo|Södra Savolax	10.380	562734.744	2031.898	156005
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	8.550	464965.622	987.053	128537
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	4.234	214971.846	2808.021	63629
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	3.735	200081.545	2001.167	56137
Åland	Åland Islands	1.40714140	75954.76520	454.6462590	19829

The Figure 13 and Table 5 show that the highest amount of potential renewable energy is situated in Lapland and the second highest in Northern Ostrobothnia. A general look at the map shows that the highest potential for renewable energy is concentrated in the north and the west coast of Finland, while the east and the south have lower values.
These theoretical values give an overview of the potential renewable energy but it does not tell the whole story. One way to see how these values can be useful is to compare them to the true amount of energy that each region uses. The table below represents the amount of electricity that each region uses. The values have been converted from GWh to PJ so that it is easier for comparing the values of renewable energies. There are four categories: the first one is housing and agriculture, the second category is industry, third

category is services and buildings and the last column is the total amount that each region uses energy. The values were taken from the Finnish Energy Industries an organization for the industrial and labor market policy of the energy sector. The Finnish Energy Industries publishes statistics about electricity consumption on a monthly, quarterly and annual level. The values used in this section were taken from the statistics Electricity use and the amount of consumers region wise.

Table 6. The amount of electricity use per region converted to PJ (Sähkön käyttö ja käyttäjämäärät maakunnittain).

NAME_2	VARNAME_2	Hous_Agr	Industry	Serv_Build	Total
Uusimaa	Uusimaa| Nyland	19.609	15.674	21.118	56.405
Lapland	Lappi|Lappland	3.902	17.802	2.840	24.548
Pirkanmaa	Pirkanmaa|Birkaland	7.106	9.036	5.188	21.330
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	6.160	10.501	4.471	21.132
Central Finland	Keski-Suomi|Mellersta Finland	4.050	13.406	2.952	20.408
Satakunta	Satakunta|Satakunda	3.348	13.532	3.413	20.297
South Karelia	Etelä-Karjala|Södra Karelen	1.915	15.311	1.714	18.940
Finland Proper	Varsinais-Suomi|Egentliga Finland	7.571	4.514	5.270	17.356
Kymenlaakso	Kymenlaakso|Kymmenedalen	2.808	10.156	3.240	16.204
Ostrobothnia	Österbotten|Pohjanmaa	4.136	5.638	1.771	11.545
North Savonia	Pohjois-Savo|Norra Savolax	3.730	4.802	2.736	11.268
North Karelia	Pohjois-Karjala|Norra Karelen	2.606	5.296	1.699	9.605
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	3.042	2.621	2.257	7.916
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	2.952	2.581	2.160	7.693
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	1.148	5.584	0.810	7.542
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	3.395	1.900	2.074	7.369
Southern Savonia	Etelä-Savo|Södra Savolax	2.786	1.411	1.757	5.954
Kainuu	Kainuu|Kajanaland	1.260	1.440	1.105	3.802
Åland	Åland Islands	0.486	0.094	0.370	0.950

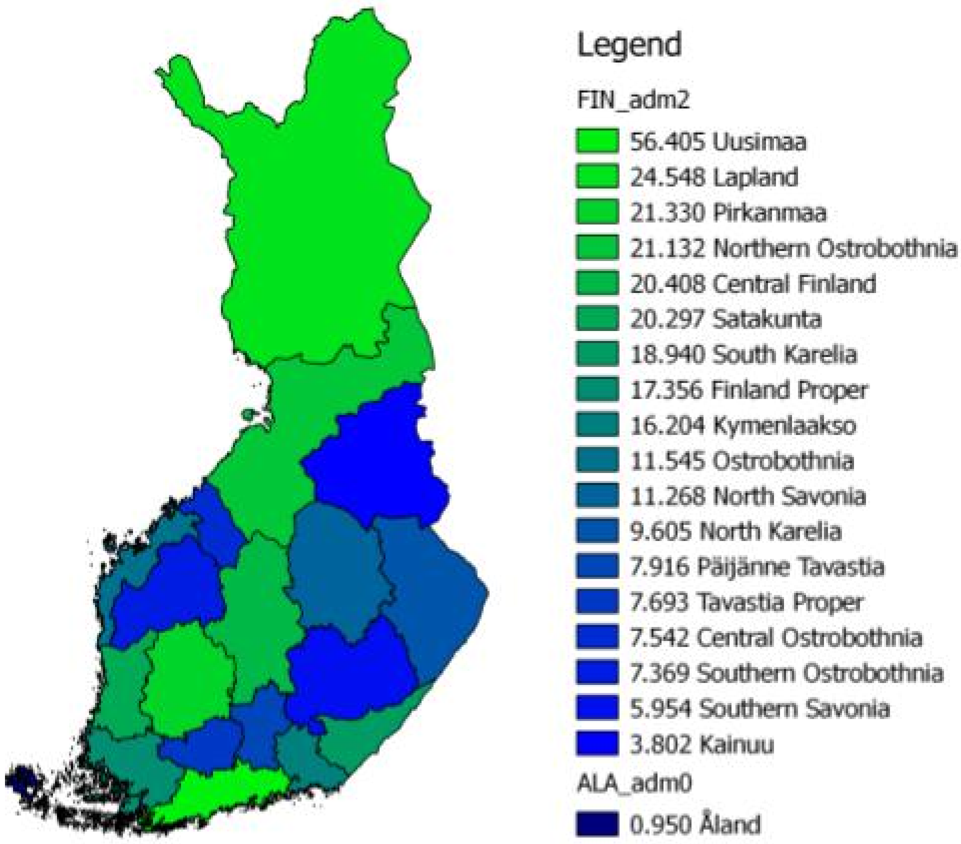

Figure 14. Represents the total electricity production of each region in PJ.

9 Potential Renewable Energy vs. Regional Electrical Usage

In this section a comparison between each region and the actual electrical energy use is looked at and to establish how much energy can be compensated by renewable energy. In the Figure 14 and appendix 8 is the electrical energy usage in each region by each section in GWh and in the Table 6 is the same values given but converted into PJ in figure 14.

9.1 Uusimaa

Uusimaa requires the most of the energy in Finland since housing and agriculture is concentrated in that region (19.609 PJ), also the second largest electrical consumer in the industry sector is concentrated in that area (15.674 PJ). The industry consists of metal, paper, chemical, electronic and food industry. The service and buildings is the

highest (21.118 PJ) due to the concentration of the population in that region. The consumer population in the region is the highest in the Finland with 918 000. In total the region consumes 56.405 PJ of energy; this is more than double than any region in Finland. On the other hand the total amount of renewable energy calculated in the thesis is 10.411 PJ which is only 18.46 % of the total required in electrical energy consumption.
The Three potential renewable energies that can be increased in that region are solar power, bioenergy and geothermal heat pumps. The total of renewable energy from these three power sources is 7.399 PJ which is equivalent in powering 111 214 middle sized households. The increase of solar power potential can be realistically done, as it has been studied by Helsinki Seudun Ympäristöpalvelu (HYS). They have mapped out the potential for solar panels in the Helsinki region and they have calculated that the amount of energy that can be potentially converted to energy is 4.320 PJ. Henna Kaisa Räsänen from HYS says that the area has a large amount of roof area that can potentially be used for solar panels and the most significant area is in the Helsinki-Vantaa airport. (metro lehti 29.10.2015). Hydro power in the region is not as significant as in other regions with only a production of 1.138 PJ. This is sufficient to provide electrical energy to 17 113 households. Untapped potential hydro power is 0.284 PJ, this would provide electricity to 4 271 households. The total amount of energy from renewable energy in Uusimaa is 10.411 PJ as mentioned above. This means that the region would be heavily dependent in importing energy from other regions that have surplus of energy or continue burning fossil fuels to compensate the shortage of electrical power.

9.2 Lapland

In Lapland the main use of energy is concentrated in the industry sector. The abundant natural resources provide unique opportunities for forestry, reindeer husbandry, steel and metal industry, mining industry and tourism. Lapland uses 17.802 PJ in that sector, while housing and agricultural electrical energy use is 3.902 PJ and services and buildings is 2.840 PJ. This is because the consumer population is little bit below average in this region (average consumer population is 181 421).
The highest form of renewable energy in Lapland is hydro power and wind power. Combined hydropower and untapped potential hydropower is equivalent to 44.955 PJ and wind power 7.205 PJ. Essentially Lapland has significant advantage in using renewable energy for its industry and in other sector. It could also provide other regions with its excessive energy to other regions that are not as fortunate as Lapland; but the remoteness of the sources of renewable energies can be a challenge to their feasibility in transporting the energy to the areas in need. The amount of bioenergy produced in Lapland

is 4.480 PJ, this could provide 67 346 households with efficient electricity. Solar power production has a potential of 0.620 PJ that could provide 9 319 Hh's with electrical energy. Geothermal heat pumps is 0.088 PJ, this could reduce the consumption of oil by 3 363 tons of oil equivalent (TOE).

9.3 Pirkanmaa

Pirkanmaa's main electrical energy usage is in the industry sector with 9.036 PJ, is concentrated in the forest and paper industry. Housing and agriculture uses 7.106 PJ and services and buildings use 5.188 PJ. The population consumer density is second highest in the country (327 000) which explains the amount of energy used in the housing and building sector. The total electrical energy consumption is 21.330 PJ.

The amount of wind power is not that significant, with a potential of 0.367 PJ. 5 519 Hh's could benefit from this power source. The potential to use solar power is the third highest (1.352 PJ) and the potential for bioenergy is 6.186 PJ. Geothermal heat pumps contribution is 0.164 PJ and could save the region 4 695 TOE. Hydropower production has been optimized (4.540 PJ) and there is no room for more hydro production. Most of the new energy would be utilized from solar power and bioenergy with a total of 7.538 PJ. This could provide energy to 113 300 households. The total energy from renewable energy is 12.608 PJ. This is not enough for the regions energy demand and Pirkanmaa would have to import almost half of the energy from its surrounding regions.

9.4 Northern Ostrobothnia

The industry in North Ostrobothnia uses 10.501 PJ. The housing and agriculture uses 6.160 PJ and services and buildings use 4.471 PJ. The main industries are wood refining, chemicals, pharmaceuticals, paper and steel. The concentration of consumers is the fourth highest in the country (244 000). The total amount of electrical energy is 21.132 PJ

The largest potential in renewable energy is in wind power with 22.613 PJ and there has been an increase in wind power production from 2014 by 47 percent. Hydro power is 16.906 PJ and an added untapped potential hydro power of 1.438 PJ can be utilized. Solar power has a potential of 1.212 PJ (19 895 Hh's) and biofuels has a potential of 6.553 PJ (98 498 Hhs). Geothermal heat pumps are the third largest from all the regions with 0.165 PJ and would save 4 715 TOE. The total energy that Northern Ostrobothnia has is 48.888 PJ. This means that there is a significant amount of untapped energy that can be utilized from renewable energy if implemented. Some of this excessive energy can be transferred to Central Ostrobothnia where production of renewable energy is low or to other areas in need of electric energy.

9.5 Central Finland

The total energy consumption for Central Finland is 20.408 PJ. The largest consumer of energy is the industry with 13.406 PJ which consists of saw mills, wood industry, paper industry and the chemical industry. Housing and agriculture uses 4.050 PJ and services and buildings uses 2.952 PJ. The total electrical energy usage is 20.408 PJ. The consumer population is just above average (185 000).

The most significant renewable energy in this region is bioenergy with a potential of 9.191 PJ could provide 138 173 households the energy needed. This is the highest potential from all the regions. A potential of 3.064 PJ can be harnessed from wind power an equivalent of providing 46 049 with sufficient energy. Hydro power is 1.167 PJ (17 539 Hh's) and solar power is 0.790 PJ (11 880). Geothermal heat pumps could save the region from burning 3 064 TOE. The total clean energy that was calculated for Central Finland is 14.320 PJ. The needs of the agriculture, housing, services and buildings can be met with these alternative energies and can also distribute the rest of it to the industry, but it would need to import more energy from its regional neighbors, such as Northern Ostrobothnia.

9.6 Satakunta

The total electrical energy usage in Satakunta is 20.297 PJ. Industry yet again plays a major role in electrical energy consumption using 13.532 PJ. Housing and agriculture is 3.348 PJ and services and buildings is 3.413 PJ. The main industry in Satakunta is energy production, heavy engineering, offshore, process industry, ports and logistics and diversified food industry. The consumer population is 154 000.

The main potential renewable energy in Satakunta is wind power with a potential to produce 6.562 PJ of energy (98 647 Hh's). The second potential is solar power with a production of 0.891 PJ (13 398 Hh's). Bioenergy has a potential of 2.867 PJ as energy wise is more than solar power, but potentially compared to other regions is not as significant (43 094 Hh's). Hydro power is 3.869 PJ is also not that significant compared to other regions. Geothermal heat pumps is 0.112 PJ is an equivalent to 3 218 TOE and an increase in hydro power is 0.027 PJ (407 Hh's). In total the energy production from renewable energy is 14.329 PJ, this is 70.6 % from the total electrical energy usage. The remaining shortage of energy can be imported outside of the region as for example Ostrobothnia.

9.7 Southern Karelia

The total electrical energy usage in Southern Karelia is 18.940 PJ. The industry uses 15.311 PJ, this is about four fifth of the total. It shows that the region is heavily industrialized. The main industry in that region is the forest industry and tourism. Housing and agriculture uses 1.915 PJ and services and buildings use 1.714 PJ. The consumer population is 94 000, hence the low electrical usage in the housing, agriculture, services and buildings.

The main renewable energy source in Southern Karelia is hydro power 7.687 PJ (115 544 Hh's). The second most abundant renewable energy source is bioenergy with 3.192 PJ (47985 Hh's). Wind power is not that significant with only 0.475 PJ (7 142 Hh's) and solar power with 0.414 PJ (6 230 Hh's). Geothermal heat pumps 0.059 PJ (1693 TOE) and potential hydro power 0.007 PJ (104 Hh's) which are not worth to mention compared to other regions. The total renewable energy that the region can produce is 11.835 PJ which easily can cover agriculture, housing, services and buildings with a left over for the industry, helping to cut down on CO_2 emissions. The remaining shortage of electrical power can be imported from Kainuu, since it has an abundant usage of renewable energy.

9.8 Finland Proper

Total energy usage in Finland proper is 17.356 PJ. Housing and agriculture is the largest consumer of energy with 7.571 PJ. Second are services and buildings with 5.270 PJ. Industries usage of energy is 4.514 PJ. Finland Proper has the second highest concentrated consumers (267 000) in the country after Uusimaa. This can be shown in the consumption of energy in the housing and agriculture sector.

The total potential renewable energy in Finland Proper is 11.745 PJ. This is 67.67% of the total electrical energy usage in that region. The main contributor in renewable energy is wind power with a contribution of 5.474 PJ (82 305 Hh's). Biofuels potential contribution is 3.233 PJ (48 603 Hh's) and solar power 2.478 PJ (37 248 Hh's). Hydro power and geothermal heat pumps are not that significant with 0.184 PJ (2 733 Hh's) and 0.167 PJ (4 780 TOE) respectively. The values show that there is a good incentive in investing in renewable energies in this region to cut down on greenhouse gasses especially in wind power. The shortage of energy can be compensated from Southern Ostrobothnia since the regions are close to each other.

9.9 Kymenlaakso

Kymenlaakso has an energy consumption of 16.204 PJ. The industry takes a large bulk of the energy usage with 10.156 PJ. Services and buildings usage is 3.240 PJ and housing and agriculture is 2.808 PJ. The amount of energy consumers is below average (126 000) and this can be seen in the values above. The main industries are the forest industry of which paper and machinery industry is the biggest contributors.

Total renewable energy of Kymenlaakso is 11.732 PJ a 72.401% of total energy consumption. Hydro power plays a major role in renewable sources by contributing 6.241 PJ of clean energy (93 810 Hh’s). From the forestry industry there is a potential of 2.441 PJ (36 693 Hh’s) in bioenergy to be harnessed and 2.324 PJ (34 956 Hh’s) from wind power plays a significant role in the production of clean energy in this region. Solar power production is 0.617 PJ (9 281 Hh’s) and from geothermal heat pumps is 0.078 PJ (2 240 TOE). Untapped potential hydro power is small in comparison with only 0.030 PJ (455 Hh’s). Since the industry is the main consumer of energy, hydro power, wind power and bioenergy can be allocated to the industry and reduce the CO_2 emissions in this region. Whereas, solar power could have a reduction of 21.97% of energy usage in the housing sector.

9.10 Ostrobothnia

In Ostrobothnia the main consumer of energy is industry with 5.638 PJ and not far behind is housing and agriculture with 4.136 PJ. There does not seem to be much services and buildings since the energy consumption is 1.771 PJ. The total energy consumption is 11.545 PJ with a consumer population well under the average (120 000). The main industries in this region are environmental technologies, metal industry, electronics, machinery and shipbuilding. The most important sector is renewable energies that include bio energy and wind power.

The highest production of renewable energy in Ostrobothnia is wind power with 13.378 PJ of potential energy equivalent to powering 201 082 Hh’s. Bioenergy comes in second with 1.917 PJ (28 820 Hh’s). These values actually coincide with what is actually happening in the region since wind power and bioenergy are the main clean tech industries in the region. Solar power is 0.664 PJ, this could provide energy for 9 985 average households. Hydro power is 0.673 PJ, but there is potential to raise that figure by 0.393 PJ, if potential hydro power is tapped in that region. Geothermal power is 0.0819 PJ, which is capable in saving the region 2 347 TOE. The total energy of Ostrobothnia is 17.108 PJ; this means that the region is a potential power house for Finland by supplying its energy to regions that lack clean energy.

9.11 Northern Savonia

Northern Savonia's total electrical energy consumption is 11.268 PJ. The industry sector takes 4.802 PJ. Most of this energy is used in the high technology, metal and food industry, wood processing and the boat industry. Housing and agriculture uses 3.730 PJ and services and buildings use 2.736 PJ. The consumer population is below average at 157 000.

The major contributor in clean renewable energy is bioenergy, contributing 9.089 PJ of energy the second highest in the country, this is equivalent in powering 135 606 Hh's. This could potentially serve the industry, housing and agriculture in the region. Hydro power produces 1.120 PJ (6 352 Hh's), the energy could be allocated to the services and building sector. Also solar power has a role to play as its energy is 0.727 PJ and can provide 10 935 households with the energy required. Geothermal heat pumps are limited to 0.107 PJ and could save energy from acquiring oil by 2 031 TOE. The total renewable energy that Northern Savonia can potentially provide is 11.551 PJ, which is a little more than the energy consumption mentioned above, this means this region could potentially become self-sufficient in energy production or at least reduce its carbon foot print in a significant way.

9.12 Northern Karelia

North Karelia's industry uses 5.296 PJ while housing and agriculture uses 2.606 PJ. The service and building sector uses 1.699 PJ of energy. The region's leading industry includes the forest, wood, food, plastic, metal, stone and tourism industry. The energy consumer population is below average at 116 000. The total energy that this region acquires is 9.605 PJ.

The most significant resource of renewable energy in North Karelia is hydro power with a potential of producing 5.494 PJ of energy (82 575 Hh's). This energy can be directed to the industry sector. In addition the bioenergy is almost as significant with 5.303 PJ (79 717 Hh's) in potential energy which can be used in the housing, agriculture, services and buildings. In addition solar power could provide average households with 0.551 PJ of electricity (8 281 Hh's). Wind power is not as significant as in the coast regions and would produce a miniscule amount of energy compared to other regions, the amount of energy production is 0.422 PJ which is sufficient to power 6 331 households. Geothermal heat pumps energy output is 0.077 PJ sufficient in replacing 2 217 TOE. It is not worth to mention the potential hydro power since it is so little. The total amount of energy that

North Karelia could potentially produce is 11.850 PJ. This shows that this region has the potential of becoming self-reliable in energy production and consumption.

9.13 Päijänne Tavastia

Housing and agriculture plays the main energy consumer in Päijänne Tavastia using 3.042 PJ of energy. Industry comes in second with 2.621 PJ. The region's industrial structure is based on many industries such as the metal, woodworking, furniture and plastic industry. Services and buildings energy usage is 2.257 PJ. The amount of energy consumers is 139 000 which is below average. The total amount of energy usage is 7.916 PJ.

From the calculations made in the thesis bioenergy seems to be the main contributor in energy production with 2.866 PJ. A combination of wind power (0.158 PJ) and solar power (0.585 PJ) would raise the energy production to 3.609 PJ; this is more than sufficient for the housing and agriculture usage. A total amount of 11 172 households would benefit. Hydro power is not significant in this region with only 0.055 PJ (830 Hh's) and geothermal heat pumps generate only 0.070 PJ that would compensate 2 001 TOE. The total calculated energy in the region is 3.735 PJ. Päijänne Tavastia would have to import most of its energy from the coastal regions to compensate the energy needed.

9.14 Tavastia Proper

Tavastia Proper's electrical energy seems to be uniformly distributed within the three sectors. Housing and agriculture is 2.952 PJ, industry 2.581 PJ and services and buildings 2.160 PJ. The total usage of energy is 7.693 PJ. The amount of consumers is 117 000.

The major contributor in renewable energy is bioenergy potentially producing 2.965 PJ (44 563 Hh's) this can be used in the housing and agriculture sector. Solar power, wind power and hydro power potentially could produce 1.196 PJ (17 962 Hh's) of energy that could be used in the services and buildings sector. Geothermal heat pumps potential to save the region form investing in oil is 2 808 TOE (0.073 PJ). The industry would have to rely from sources outside of the region. The total renewable energy calculated is 4.234 PJ is equivalent in providing energy to 63 629 households.

9.15 Central Ostrobothnia

In comparing the values given in the appendix 8, industry is the key player in the consumption of electrical energy in Central Ostrobothnia. The chemical industry requires a major part of the energy that is produced such as Kemira a chemical conglomerate. Also in the region there is metalworking, casting, textiles, plastics, food and carpentry. The energy required for the industry is 5.548 PJ. Housing and agriculture usage is 1.148 PJ and services and buildings is 0.810 PJ. The total energy required for the region is 7.542 PJ. The consumer population is 41 000 the lowest in Finland excluding Åland.

Wind power has the potential of producing 6.529 PJ (98 160 Hh's) of energy for the region. This would be sufficient for the industry. Bioenergy production is 1.759 PJ. This could be used in the housing and agriculture sector with a calculated energy potential for 26 438 households. Solar power potential is 0.135 PJ, converted potential usage for households is 2 032 Hh's. Hydropower is low in energy in this region and is equivalent in providing 1 375 Hh's with sufficient energy. Geothermal heat pumps is 0.034 PJ translated to conversion of oil units is 987 TOE. Untapped hydro potential energy is so insignificant that it is not worth mentioning. The total energy that the region potentially could produce is 8.550 PJ. This is over the amount of energy that is required in the region and indicates that Central Ostrobothnia could become self-sufficient in its energy production and consumption.

9.16 Southern Ostrobothnia

The major consumer of electrical energy in Southern Ostrobothnia is housing and agriculture, using 3.395 PJ of energy. Services and buildings usage is 2.074 PJ and there seems to be a low industry since the usage of energy is 1.900 PJ that is concentrated in food production. The total amount of energy is 7.369 PJ. The consumer population is 124 000.

As Southern Ostrobothnia is a coastal region its potential wind production could be of importance as shown in its potential energy 6.756 PJ (101 569 Hh's). This is sufficient to power housing, agriculture and the industry. Also bioenergy could be of significance as calculated to be 5.192 PJ (78 039 Hh's). The amount harnessed from solar power is 0.848 PJ this could give energy to 12 752 Hh's. Hydro power is 0.993 PJ this is equivalent in giving 14 932 Hh's the required energy. Geothermal heat pumps is 0.102 PJ; converted to tones of oil equivalent is 2 936 TOE. The total potential renewable energy is 13.892 PJ this is more than enough for the region. Some of the excessive energy could be transferred to its neighboring regions such as Tavastia Proper that is lacking energy from its renewable sources.

9.17 Southern Savonia

Housing and agriculture are the major source of electrical energy use in Southern Savonia, using 2.786 PJ. Services and buildings use 1.757 PJ and industries consumption is 1.411 PJ. The industry is concentrated on the wood industry producing Plywood. The total energy usage in the region is 5.954 PJ. The consumer population in the region is 127 000.

Bioenergy is the main contributor in clean energy is Southern Savonia with the third highest value in Finland at 9.021 PJ, since the region is rich in forestry. This amount of energy has the potential of powering 134 606 households. Southern Savonia could become self-sufficient just by applying bioenergy as its main resource in the production of energy. The other energy sources are not as significant. Wind power is 0.336 PJ since Southern Savonia is situated inland. The amount of energy is in comparison to 5 032 Hh's. Solar power production is 0.529 PJ and the calculated potential is 7 949 Hh's. Hydro power is also limited to 0.423 PJ and equivalent to 6 352 Hh's. Geothermal heat pumps is 0.071 PJ and converted to oil equivalent is 2 031 TOE. The total amount of energy production in Southern Savonia is 10.380 PJ. From the data it is clear that Southern Savonia can meet its demands in energy usage and also can provide energy to other regions in need as for example Päijänne Tavastia, which is not self-reliable in energy.

9.18 Kainuu

The total electricity usage in Kainuu is the lowest from all the regions within the mainland, which shows that the region is underdeveloped. The industry uses 1.440 PJ of electrical power. The industry is mainly driven by sawmill, lumber and the paper industry. Housing and agriculture usage of electrical energy is 1.260 PJ and services and buildings is 1.105 PJ. The total amount of electrical energy is 3.802 PJ. The consumer population is 57 000. Hydro power generates the most power in Kainuu by 10.126 PJ (152 210 Hh's). Bioenergy is the second largest factor by potentially producing 4.785 PJ. Bioenergy alone could supply the electrical usage in Kainuu for 71 930 Hh's. Wind power is 0.910 PJ and that could potentially supply power to 13 690 Hh's. Solar power is 0.279 PJ and is equivalent in providing electricity to 4 192 Hh's. Geothermal is not that significant since the housing sector is not that large, the amount of energy production is 0.038 PJ and potentially could save 1 084 TOE. The total energy production is 16.138; this makes it the fourth largest in the country. Kainuu can be seen as a power house since the potential of energy production is almost four times greater than its electrical consumption. Some of its excessive energy can be allocated to other regions in the country that lack electrical power from renewables such as Uusimaa.

9.19 Åland Islands

Electrical usage in Åland is mainly concentrated in the housing and agriculture sector with 0.486 PJ. Services and buildings usage is 0.370 PJ and the industry is a mere 0.094

PJ. The total amount of electrical energy is 0.950 PJ. The consumer population is the lowest from all the regions and is 24 000.

As Åland is an island, this gives it an advantage to build wind farms out in the surrounding sea. The potential for wind power is 1.138 PJ; this amount of potential energy could meet its demand for the electrical power that is required in the island and become reliable on clean energy. Solar power is the second largest producer of clean energy with 0.149 PJ that could provide electrical power to 2 241 homes. Geothermal heat pumps potential energy is 0.0159 PJ which could save the island from burning 454.6 TOE. The total amount of energy in Åland is 1.407 PJ. Åland could potentially be self-sufficient in the production of electricity from renewable energies.

9.20 Tons of coal equivalent

The thesis also made a comparison on how much tons of coal equivalent (TCE) would be saved from going into the furnace to generate electricity. The values are not mentioned above so as not to overwhelm the reader, but they can be seen in the appendix region wise. The total amount of coal for Finland calculated in the thesis is 15 093 175.020 TCE, corresponding to approximately 283 PJ. This value takes into account that the power plants efficiency is 40%. Finland used in 2014 a total amount of 3.8 million tons of hard coal in the production of electricity and heat, corresponding to approximately 97 PJ (statistics Finland). This value is the amount that Finland used in powering it power plants. The value of TCE is just a way for the reader to make a comparison on how much coal would be needed to convert the energy from renewable energies.

10 Conclusion

Investigating the amount of potential renewable energy each region can produce, it was shown that the largest amount of energy production is wind power, bioenergy and hydropower. Solar power, geothermal heat pumps and small scale hydropower were of a less importance, but it does not mean that solar power and thermal heat pumps do not have the capacity to increase in the future or by 2020. This depends on the trends and governmental policies in the region. Small scale hydropower seems to be limited and not much increase in that sector compared to the other renewable energies

A comparison between Figure 13 and 14 shows, that most of the renewable energy is situated in the eastern coastal areas with the exception of Kainuu. This is due to the substantial production in energy in hydropower, wind power and bioenergy. The main power houses of potential renewable energies are: Lapland, Northern Ostrobothnia, Ostrobothnia, Kainuu, Southern Ostrobothnia, North Karelia and South Savonia. The main regions that consume electrical energy and would need a substantial amount of electrical energy to be compensated are: Uusimaa, Pirkanmaa, Central Finland Satakunta, South Karelia, Finland Proper, Kymenlaakso, Päijänne Tavastia and Tavastia Proper. The regions that are self-sufficient are Northern Savonia and the Åland islands.

The amount of electrical consumption for Finland in 2014 was 290.149 PJ and the amount of calculated renewable energy is 292.062 PJ. In theory Finland has the capacity to convert all its electrical usage from renewables, but the obstacle is that, it is not evenly distributed throughout the regions. As an example, Uusimaa is by far the most electrical intensive consumer in the region. The region is situated in the south and the largest regions that produce excessive renewable energy are situated in the north of the country. Transporting that energy to the south without a drop in the voltage and maintaining a steady electrical current is the challenge that would have to be addressed. For example, wind power and solar power are somewhat unreliable energy sources, since they are heavily dependent on the source of the energy, i.e. wind and irradiation. To overcome these obstacles, there needs to be a strategy of a mixture between fossil based energy and renewables. Whereas, fossil fuels would be used only as a backup source of energy on a bad day.

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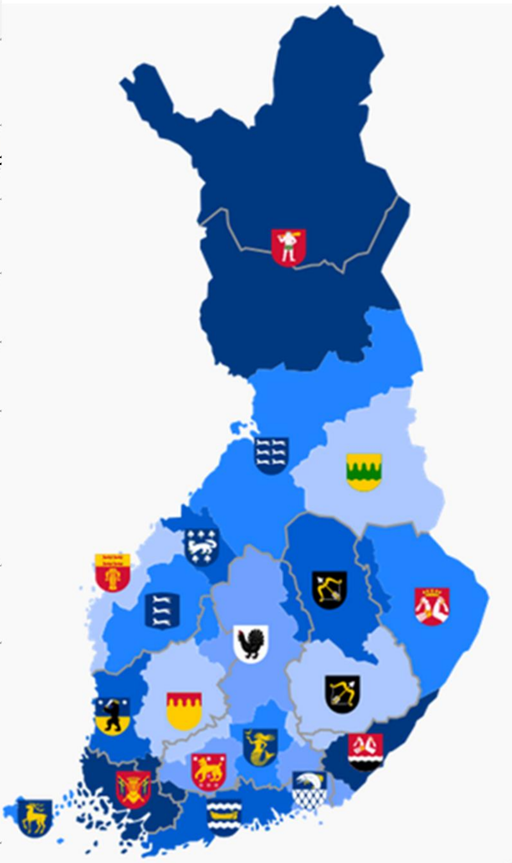
Regions of Finland

Coat of Arms	English name
	Lapland
	Northern Ostrobothnia
	Kainuu
	North Karelia
	Northern Savonia
	Southern Savonia
	Southern Ostrobothnia
	Central Ostrobothnia
	Ostrobothnia
	Pirkanmaa
	Central Finland
	Satakunta
	Southwest Finland
	South Karelia
	Päijät-Häme
	Tavastia Proper
	Uusimaa
	Kymenlaakso
	Aland[1]



Regions of Finland
(the borders of historical provinces are shown in grey)

Figure 1. The regions of Finland

Figures, tables and calculations for potential wind power

Table 1 locations of wind turbines and capacity

	Province	Longitude	Latitude	Num.Turbin	MW_min	MW_max.
0	Lappi	23.80930000000...	67.92350000000...	15	30.00000000000...	45.00000000000...
1	Lappi	25.77939999999...	67.64610000000...	20	40.00000000000...	60.00000000000...
2	Lappi	26.20820000000...	67.33339999999...	9	27.00000000000...	27.00000000000...
3	Lappi	27.08670000000...	66.71760000000...	12	36.00000000000...	36.00000000000...
4	Lappi	27.83320000000...	66.66759999999...	9	27.00000000000...	27.00000000000...
5	Lappi	27.07010000000...	66.56759999999...	9	27.00000000000...	27.00000000000...
6	Lappi	27.05010000000...	66.04009999999...	11	22.00000000000...	33.00000000000...
7	Lappi	28.14650000000...	66.16759999999...	51	68.00000000000...	153.0000000000...
8	Lappi	27.91760000000...	65.86759999999...	6	14.00000000000...	18.00000000000...
9	Lappi	24.03980000000...	66.53319999999...	21	63.00000000000...	130.0000000000...
10	Lappi	23.77760000000...	66.29009999999...	15	30.00000000000...	75.00000000000...
11	Lappi	24.04870000000...	66.13209999999...	8	20.00000000000...	24.00000000000...
12	Lappi	24.87760000000...	66.15430000000...	10	30.00000000000...	30.00000000000...
13	Lappi	24.74869999999...	66.13649999999...	3	6.000000000000...	15.00000000000...
14	Lappi	24.22759999999...	65.73399999999...	45	54.00000000000...	225.0000000000...
15	Lappi	24.14600000000...	65.76680000000...	12	43.00000000000...	43.00000000000...
16	Lappi	24.53930000000...	65.65569999999...	12	36.00000000000...	36.00000000000...
17	Lappi	24.54899999999...	65.66800000000...	3	9.000000000000...	9.000000000000...
18	Lappi	24.54070000000...	65.61860000000...	30	99.00000000000...	185.0000000000...
19	Lappi	24.87229999999...	65.68189999999...	40	120.0000000000...	240.0000000000...
20	Lappi	25.01340000000...	65.67149999999...	7	31.00000000000...	31.00000000000...
21	Lappi	25.04319999999...	65.65089999999...	40	120.0000000000...	200.0000000000...
22	Lappi	25.10500000000...	65.61339999999...	3	9.000000000000...	9.000000000000...

23	Lappi	21.33680000000...	68.78300000000...	1	0.500000000000...	0.500000000000...
24	Lappi	27.14450000000...	67.43439999999...	34	81.00000000000...	102.0000000000...
25	Lappi	27.10699999999...	67.49030000000...	25	50.00000000000...	75.00000000000...
26	Kainuu	28.23030000000...	64.78619999999...	8	24.00000000000...	24.00000000000...
27	Kainuu	28.69849999999...	64.68739999999...	8	24.00000000000...	24.00000000000...
28	Kainuu	28.26269999999...	64.65850000000...	10	24.00000000000...	30.00000000000...
29	Kainuu	27.29380000000...	64.41649999999...	22	66.00000000000...	66.00000000000...
30	Northen_Ostrob...	25.11469999999...	65.55029999999...	8	6.000000000000...	6.000000000000...
31	Northen_Ostrob...	25.32829999999...	65.55190000000...	19	50.00000000000...	50.00000000000...
32	Northen_Ostrob...	25.30870000000...	65.49089999999...	8	20.00000000000...	20.00000000000...
33	Northen_Ostrob...	25.36820000000...	65.48669999999...	11	33.00000000000...	33.00000000000...
34	Northen_Ostrob...	25.25959999999...	65.41089999999...	1	1.000000000000...	1.000000000000...
35	Northen_Ostrob...	25.40570000000...	65.30159999999...	5	6.000000000000...	15.00000000000...
36	Northen_Ostrob...	25.28770000000...	65.39220000000...	1	1.000000000000...	1.000000000000...
37	Northen_Ostrob...	25.25010000000...	65.40059999999...	5	6.000000000000...	15.00000000000...
38	Northen_Ostrob...	24.60660000000...	65.26819999999...	80	240.0000000000...	400.0000000000...
39	Northen_Ostrob...	24.99119999999...	65.20839999999...	null	100.0000000000...	150.0000000000...
40	Northen_Ostrob...	25.01040000000...	65.16570000000...	null	400.0000000000...	650.0000000000...
41	Northen_Ostrob...	25.41330000000...	65.24729999999...	4	8.000000000000...	20.00000000000...
42	Northen_Ostrob...	24.54710000000...	65.03940000000...	1	0.300000000000...	0.300000000000...
43	Northen_Ostrob...	25.06319999999...	65.03780000000...	1	0.500000000000...	0.500000000000...
44	Northen_Ostrob...	25.14560000000...	65.02509999999...	25	60.00000000000...	125.0000000000...
45	Northen_Ostrob...	25.20820000000...	65.00549999999...	5	9.000000000000...	9.000000000000...
46	Northen_Ostrob...	25.10579999999...	64.93999999999...	1	2.000000000000...	2.000000000000...
47	Northen_Ostrob...	25.09090000000...	64.92889999999...	1	0.700000000000...	0.700000000000...
48	Northen_Ostrob...	25.19950000000...	64.89090000000...	3	6.000000000000...	6.000000000000...
49	Northen_Ostrob...	24.81100000000...	64.88819999999...	2	0.600000000000...	0.600000000000...
50	Northen_Ostrob...	24.54799999999...	64.80700000000...	2	0.600000000000...	0.600000000000...
51	Northen_Ostrob...	24.39689999999...	64.64340000000...	11	26.00000000000...	26.00000000000...
52	Northen_Ostrob...	24.75090000000...	64.53310000000...	7	21.00000000000...	21.00000000000...
53	Northen_Ostrob...	24.39560000000...	64.33410000000...	6	14.00000000000...	14.00000000000...
54	Northen_Ostrob...	28.74020000000...	65.99710000000...	9	22.00000000000...	27.00000000000...
55	Northen_Ostrob...	27.62920000000...	65.26690000000...	22	60.00000000000...	100.0000000000...
56	Northen_Ostrob...	26.75890000000...	64.28000000000...	27	80.00000000000...	80.00000000000...
57	Northen_Ostrob...	26.77959999999...	64.06449999999...	127	255.0000000000...	381.0000000000...
58	Northen_Ostrob...	26.13700000000...	63.53620000000...	8	18.00000000000...	26.00000000000...
59	Northen_Ostrob...	25.75219999999...	63.70190000000...	25	50.00000000000...	75.00000000000...
60	Northen_Ostrob...	25.60290000000...	63.77859999999...	9	27.00000000000...	30.00000000000...
61	Northen_Ostrob...	25.31960000000...	63.74850000000...	2	7.000000000000...	7.000000000000...
62	Northen_Ostrob...	25.34499999999...	63.78810000000...	9	27.00000000000...	30.00000000000...
63	Northen_Ostrob...	25.13360000000...	63.99629999999...	9	12.00000000000...	27.00000000000...
64	Northen_Ostrob...	25.06370000000...	64.00799999999...	9	27.00000000000...	30.00000000000...
65	Northen_Ostrob...	24.95390000000...	63.92960000000...	2	7.000000000000...	7.000000000000...
66	Northen_Ostrob...	24.54570000000...	63.88329999999...	8	16.00000000000...	24.00000000000...
67	Northen_Ostrob...	24.50880000000...	64.00069999999...	9	12.00000000000...	27.00000000000...
68	Northen_Ostrob...	24.80870000000...	64.11329999999...	9	12.00000000000...	27.00000000000...

69	Northen_Ostrob...	23.65449999999...	64.06220000000...	25	60.00000000000...	100.0000000000...
70	Northen_Ostrob...	23.78709999999...	64.13089999999...	10	30.00000000000...	30.00000000000...
71	Northen_Ostrob...	23.92099999999...	64.18200000000...	9	27.00000000000...	30.00000000000...
72	Northen_Ostrob...	24.04850000000...	64.19769999999...	2	6.000000000000...	6.000000000000...
73	Northen_Ostrob...	23.98730000000...	64.30989999999...	12	36.00000000000...	36.00000000000...
74	Northen_Ostrob...	23.97820000000...	64.33400000000...	26	60.00000000000...	83.00000000000...
75	Northen_Ostrob...	24.05859999999...	64.36300000000...	11	33.00000000000...	33.00000000000...
76	Northen_Ostrob...	24.11250000000...	64.32940000000...	8	24.00000000000...	24.00000000000...
77	Northen_Ostrob...	24.14740000000...	64.42430000000...	6	18.00000000000...	18.00000000000...
78	Northen_Ostrob...	24.25529999999...	64.35370000000...	40	90.00000000000...	120.0000000000...
79	Northen_Ostrob...	24.22710000000...	64.24779999999...	6	20.00000000000...	20.00000000000...
80	Northen_Ostrob...	24.32829999999...	64.21439999999...	9	12.00000000000...	27.00000000000...
81	Northen_Ostrob...	24.44180000000...	64.29770000000...	4	13.00000000000...	13.00000000000...
82	Northen_Ostrob...	24.69140000000...	64.28159999999...	8	16.00000000000...	24.00000000000...
83	Northen_Ostrob...	24.62640000000...	64.38670000000...	9	20.00000000000...	27.00000000000...
84	Northen_Ostrob...	24.64580000000...	64.41219999999...	9	30.00000000000...	30.00000000000...
85	Northen_Ostrob...	24.64950000000...	64.43859999999...	26	62.00000000000...	130.0000000000...
86	Northen_Ostrob...	24.65579999999...	64.46210000000...	19	57.00000000000...	95.00000000000...
87	Northen_Ostrob...	24.84969999999...	64.41190000000...	10	30.00000000000...	45.00000000000...
88	Northen_Ostrob...	24.27639999999...	64.49200000000...	15	30.00000000000...	75.00000000000...
89	Northen_Ostrob...	24.85729999999...	64.54319999999...	10	25.00000000000...	45.00000000000...
90	Northen_Ostrob...	24.15070000000...	64.58969999999...	72	216.0000000000...	360.0000000000...
91	Northen_Ostrob...	24.37040000000...	64.57699999999...	40	120.0000000000...	120.0000000000...
92	Northen_Ostrob...	24.49320000000...	64.59250000000...	4	10.00000000000...	10.00000000000...
93	Northen_Ostrob...	24.55529999999...	64.58400000000...	10	33.00000000000...	33.00000000000...
94	Northen_Ostrob...	24.76330000000...	64.57059999999...	40	50.00000000000...	114.0000000000...
95	Northen_Ostrob...	24.79629999999...	64.58190000000...	44	100.0000000000...	132.0000000000...
96	Northen_Ostrob...	24.72190000000...	64.62120000000...	30	40.00000000000...	120.0000000000...
97	Northen_Ostrob...	24.67610000000...	64.65800000000...	11	30.00000000000...	30.00000000000...
98	Northen_Ostrob...	24.73320000000...	64.70690000000...	20	40.00000000000...	40.00000000000...
99	Northen_Ostrob...	24.18499999999...	64.70730000000...	24	48.00000000000...	72.00000000000...
100	Northen_Ostrob...	24.38690000000...	64.75860000000...	70	140.0000000000...	210.0000000000...
101	Northen_Ostrob...	24.93070000000...	64.78189999999...	8	16.00000000000...	24.00000000000...
102	Northen_Ostrob...	24.90429999999...	64.78409999999...	9	27.00000000000...	27.00000000000...
103	Northen_Ostrob...	24.85310000000...	64.80180000000...	24	48.00000000000...	72.00000000000...
104	Northen_Ostrob...	24.92690000000...	64.80859999999...	14	28.00000000000...	56.00000000000...
105	Northen_Ostrob...	25.18710000000...	64.83759999999...	2	6.000000000000...	6.000000000000...
106	Northen_Ostrob...	25.19950000000...	64.89090000000...	3	6.000000000000...	6.000000000000...
107	Northen_Ostrob...	25.39689999999...	65.00889999999...	1	1.000000000000...	1.000000000000...
108	Northen_Ostrob...	25.39740000000...	65.01179999999...	1	3.000000000000...	3.000000000000...
109	Northen_Ostrob...	25.07049999999...	64.43559999999...	9	12.00000000000...	20.00000000000...
110	Northen_Ostrob...	24.85729999999...	64.50289999999...	10	25.00000000000...	45.00000000000...
111	Northen_Ostrob...	25.16560000000...	64.68619999999...	8	14.00000000000...	24.00000000000...
112	Northen_Ostrob...	24.04840000000...	64.25709999999...	22	73.00000000000...	73.00000000000...
113	Central_Ostrobo...	24.07030000000...	64.05110000000...	100	108.0000000000...	300.0000000000...
114	Central_Ostrobo...	23.91760000000...	63.86500000000...	17	28.00000000000...	51.00000000000...

115	Central_Ostrobo...	24.09440000000...	63.76429999999...	40	105.0000000000...	120.0000000000...
116	Central_Ostrobo...	23.08040000000...	63.85110000000...	null	20.00000000000...	100.0000000000...
117	Central_Ostrobo...	23.91760000000...	63.86500000000...	17	28.00000000000...	51.00000000000...
118	Central_Ostrobo...	24.09440000000...	63.76429999999...	40	105.0000000000...	120.0000000000...
119	Central_Ostrobo...	24.48710000000...	63.68480000000...	90	231.0000000000...	270.0000000000...
120	Central_Ostrobo...	24.68840000000...	63.46999999999...	87	300.0000000000...	300.0000000000...
121	Central_Ostrobo...	24.23930000000...	63.36889999999...	9	27.00000000000...	41.00000000000...
122	Central_Ostrobo...	24.18150000000...	63.48519999999...	8	24.00000000000...	36.00000000000...
123	Central_Ostrobo...	23.03379999999...	63.86820000000...	2	2.000000000000...	2.000000000000...
124	Central_Ostrobo...	23.02799999999...	63.85479999999...	4	12.00000000000...	12.00000000000...
125	Ostrobothnia	22.78170000000...	63.83129999999...	1	1.000000000000...	1.000000000000...
126	Ostrobothnia	21.30849999999...	62.25759999999...	3	3.000000000000...	3.000000000000...
127	Ostrobothnia	21.13550000000...	62.47440000000...	1	0.800000000000...	0.800000000000...
128	Ostrobothnia	21.18230000000...	62.93099999999...	2	0.400000000000...	0.400000000000...
129	Ostrobothnia	21.55200000000...	63.05639999999...	1	3.600000000000...	3.600000000000...
130	Ostrobothnia	22.78170000000...	63.83129999999...	1	1.000000000000...	1.000000000000...
131	Ostrobothnia	23.03379999999...	63.86820000000...	2	2.000000000000...	2.000000000000...
132	Ostrobothnia	21.49340000000...	62.05830000000...	50	60.00000000000...	150.0000000000...
133	Ostrobothnia	21.56380000000...	62.09920000000...	34	68.00000000000...	170.0000000000...
134	Ostrobothnia	21.61779999999...	62.11789999999...	6	18.00000000000...	18.00000000000...
135	Ostrobothnia	21.60600000000...	62.12069999999...	26	78.00000000000...	78.00000000000...
136	Ostrobothnia	21.51119999999...	62.13909999999...	25	75.00000000000...	125.0000000000...
137	Ostrobothnia	21.42680000000...	62.24119999999...	5	15.00000000000...	15.00000000000...
138	Ostrobothnia	21.59870000000...	62.31400000000...	60	180.0000000000...	300.0000000000...
139	Ostrobothnia	21.60279999999...	62.71360000000...	26	30.00000000000...	60.00000000000...
140	Ostrobothnia	21.52049999999...	62.75170000000...	20	30.00000000000...	60.00000000000...
141	Ostrobothnia	21.93009999999...	62.81060000000...	25	30.00000000000...	60.00000000000...
142	Ostrobothnia	22.25420000000...	62.90590000000...	89	129.0000000000...	267.0000000000...
143	Ostrobothnia	22.60699999999...	63.31300000000...	32	21.00000000000...	96.00000000000...
144	Ostrobothnia	22.67299999999...	63.66819999999...	2	6.000000000000...	6.000000000000...
145	Ostrobothnia	22.30020000000...	63.44019999999...	9	27.00000000000...	27.00000000000...
146	Ostrobothnia	22.23250000000...	63.18399999999...	5	15.00000000000...	15.00000000000...
147	Ostrobothnia	22.15780000000...	63.19039999999...	3	9.000000000000...	9.000000000000...
148	Ostrobothnia	21.99950000000...	63.12250000000...	25	75.00000000000...	125.0000000000...
149	Ostrobothnia	21.18339999999...	63.21379999999...	36	20.69999999999...	180.0000000000...
150	Ostrobothnia	21.26670000000...	62.85999999999...	32	15.00000000000...	120.0000000000...
151	Ostrobothnia	21.27270000000...	62.82309999999...	5	15.00000000000...	15.00000000000...
152	Ostrobothnia	21.18290000000...	62.78609999999...	4	12.00000000000...	12.00000000000...
153	Ostrobothnia	21.20629999999...	62.76030000000...	6	12.00000000000...	18.00000000000...
154	Ostrobothnia	21.20540000000...	62.71940000000...	9	18.00000000000...	27.00000000000...
155	Ostrobothnia	21.37979999999...	62.63069999999...	28	54.00000000000...	84.00000000000...
156	Ostrobothnia	21.29840000000...	62.58229999999...	28	56.00000000000...	140.0000000000...
157	Ostrobothnia	21.21079999999...	62.55919999999...	4	12.00000000000...	20.00000000000...
158	Ostrobothnia	21.16649999999...	62.50630000000...	18	36.00000000000...	54.00000000000...
159	Ostrobothnia	21.30099999999...	62.48890000000...	37	130.0000000000...	130.0000000000...
160	Ostrobothnia	21.35480000000...	62.43169999999...	42	140.0000000000...	140.0000000000...

46	Northen_Ostrob...	25.10579999999...	64.93999999999...	1	2.000000000000...	2.000000000000...
47	Northen_Ostrob...	25.09090000000...	64.92889999999...	1	0.700000000000...	0.700000000000...
48	Northen_Ostrob...	25.19950000000...	64.89090000000...	3	6.000000000000...	6.000000000000...
49	Northen_Ostrob...	24.81100000000...	64.88819999999...	2	0.600000000000...	0.600000000000...
50	Northen_Ostrob...	24.54799999999...	64.80700000000...	2	0.600000000000...	0.600000000000...
51	Northen_Ostrob...	24.39689999999...	64.64340000000...	11	26.00000000000...	26.00000000000...
52	Northen_Ostrob...	24.75090000000...	64.53310000000...	7	21.00000000000...	21.00000000000...
53	Northen_Ostrob...	24.39560000000...	64.33410000000...	6	14.00000000000...	14.00000000000...
54	Northen_Ostrob...	28.74020000000...	65.99710000000...	9	22.00000000000...	27.00000000000...
55	Northen_Ostrob...	27.62920000000...	65.26690000000...	22	60.00000000000...	100.0000000000...
56	Northen_Ostrob...	26.75890000000...	64.28000000000...	27	80.00000000000...	80.00000000000...
57	Northen_Ostrob...	26.77959999999...	64.06449999999...	127	255.0000000000...	381.0000000000...
58	Northen_Ostrob...	26.13700000000...	63.53620000000...	8	18.00000000000...	26.00000000000...
59	Northen_Ostrob...	25.75219999999...	63.70190000000...	25	50.00000000000...	75.00000000000...
60	Northen_Ostrob...	25.60290000000...	63.77859999999...	9	27.00000000000...	30.00000000000...
61	Northen_Ostrob...	25.31960000000...	63.74850000000...	2	7.000000000000...	7.000000000000...
62	Northen_Ostrob...	25.34499999999...	63.78810000000...	9	27.00000000000...	30.00000000000...
63	Northen_Ostrob...	25.13360000000...	63.99629999999...	9	12.00000000000...	27.00000000000...
64	Northen_Ostrob...	25.06370000000...	64.00799999999...	9	27.00000000000...	30.00000000000...
65	Northen_Ostrob...	24.95390000000...	63.92960000000...	2	7.000000000000...	7.000000000000...
66	Northen_Ostrob...	24.54570000000...	63.88329999999...	8	16.00000000000...	24.00000000000...
67	Northen_Ostrob...	24.50880000000...	64.00069999999...	9	12.00000000000...	27.00000000000...
68	Northen_Ostrob...	24.80870000000...	64.11329999999...	9	12.00000000000...	27.00000000000...
184	Southern_Ostrob...	24.30790000000...	62.95870000000...	23	46.00000000000...	69.00000000000...
185	Southern_Ostrob...	24.13660000000...	63.01299999999...	19	95.00000000000...	95.00000000000...
186	Southern_Ostrob...	23.21219999999...	63.29899999999...	3	9.000000000000...	9.000000000000...
187	Southern_Ostrob...	23.00610000000...	63.31909999999...	1	3.000000000000...	3.000000000000...
188	Southern_Ostrob...	22.98310000000...	63.35680000000...	6	18.00000000000...	24.00000000000...
189	Southern_Ostrob...	22.87340000000...	63.23100000000...	2	4.000000000000...	6.000000000000...
190	Southern_Ostrob...	23.05150000000...	62.94760000000...	9	18.00000000000...	27.00000000000...
191	Central_Finland	24.36649999999...	63.09819999999...	9	27.00000000000...	27.00000000000...
192	Central_Finland	24.55099999999...	63.02349999999...	9	25.00000000000...	25.00000000000...
193	Central_Finland	24.85030000000...	63.07410000000...	9	27.00000000000...	29.69999999999...
194	Central_Finland	25.09600000000...	63.38960000000...	9	27.00000000000...	29.69999999999...
195	Central_Finland	25.63280000000...	63.31060000000...	6	20.00000000000...	20.00000000000...
196	Central_Finland	25.60460000000...	63.29160000000...	9	20.69999999999...	27.00000000000...
197	Central_Finland	25.60950000000...	63.27669999999...	14	42.00000000000...	70.00000000000...
198	Central_Finland	26.30930000000...	62.70949999999...	5	15.00000000000...	21.00000000000...
199	Central_Finland	25.23389999999...	62.73610000000...	4	12.00000000000...	12.00000000000...
200	Central_Finland	25.00920000000...	62.69550000000...	4	10.00000000000...	18.00000000000...
201	Central_Finland	24.95660000000...	62.62639999999...	13	39.00000000000...	39.00000000000...
202	Central_Finland	25.63459999999...	62.04930000000...	4	18.00000000000...	18.00000000000...
203	Central_Finland	25.29949999999...	61.99589999999...	3	7.000000000000...	10.00000000000...
204	Central_Finland	25.79070000000...	61.74700000000...	6	18.00000000000...	18.00000000000...
205	Central_Finland	24.95690000000...	62.62639999999...	40	80.00000000000...	120.0000000000...
206	Finland_Proper	21.42840000000...	60.94700000000...	8	24.00000000000...	24.00000000000...

207	Finland_Proper	21.47820000000...	60.90489999999...	18	54.00000000000...	54.00000000000...
208	Finland_Proper	21.27639999999...	60.78849999999...	2	6.000000000000...	6.000000000000...
209	Finland_Proper	21.34100000000...	60.78860000000...	2	2.600000000000...	2.600000000000...
210	Finland_Proper	21.37099999999...	60.80250000000...	5	15.00000000000...	15.00000000000...
211	Finland_Proper	21.38289999999...	60.68119999999...	4	10.00000000000...	10.00000000000...
212	Finland_Proper	21.38130000000...	60.67700000000...	8	24.00000000000...	24.00000000000...
213	Finland_Proper	21.63850000000...	60.73290000000...	15	45.00000000000...	82.50000000000...
214	Finland_Proper	21.38130000000...	60.67680000000...	5	18.00000000000...	18.00000000000...
215	Finland_Proper	21.61469999999...	60.53820000000...	1	2.000000000000...	3.000000000000...
216	Finland_Proper	22.07860000000...	60.60240000000...	1	5.000000000000...	5.000000000000...
217	Finland_Proper	22.84369999999...	60.63649999999...	6	18.00000000000...	20.00000000000...
218	Finland_Proper	23.54459999999...	60.64730000000...	4	8.000000000000...	12.00000000000...
219	Finland_Proper	23.52540000000...	60.64929999999...	27	135.0000000000...	135.0000000000...
220	Finland_Proper	22.81570000000...	60.37369999999...	9	27.00000000000...	27.00000000000...
221	Finland_Proper	22.70130000000...	60.34479999999...	3	12.00000000000...	12.00000000000...
222	Finland_Proper	22.69409999999...	60.24609999999...	4	8.000000000000...	8.000000000000...
223	Finland_Proper	22.62630000000...	60.18350000000...	4	9.000000000000...	16.00000000000...
224	Finland_Proper	22.75029999999...	60.16310000000...	18	54.00000000000...	54.00000000000...
225	Finland_Proper	22.54880000000...	60.12850000000...	31	74.40000000000...	124.0000000000...
226	Finland_Proper	22.50219999999...	60.09400000000...	5	10.00000000000...	15.00000000000...
227	Finland_Proper	22.26760000000...	60.13880000000...	1	2.000000000000...	2.000000000000...
228	Finland_Proper	21.67820000000...	60.16310000000...	1	2.000000000000...	2.000000000000...
229	Finland_Proper	20.93580000000...	60.15650000000...	40	105.0000000000...	120.0000000000...
230	Finland_Proper	22.33589999999...	59.94500000000...	3	6.000000000000...	6.000000000000...
231	Finland_Proper	22.63459999999...	60.03880000000...	9	18.00000000000...	27.00000000000...
232	Finland_Proper	23.19129999999...	60.12189999999...	7	23.00000000000...	35.00000000000...
233	Finland_Proper	22.69739999999...	60.85640000000...	4	8.000000000000...	12.00000000000...
234	Finland_Proper	22.59680000000...	60.80160000000...	6	18.00000000000...	20.00000000000...
235	Finland_Proper	21.99320000000...	60.11970000000...	3	13.00000000000...	17.00000000000...
236	Finland_Proper	23.02489999999...	60.43650000000...	3	15.00000000000...	15.00000000000...
237	Finland_Proper	23.13459999999...	60.80080000000...	4	12.00000000000...	12.00000000000...
238	Finland_Proper	23.00880000000...	60.68800000000...	9	27.00000000000...	27.00000000000...
239	Finland_Proper	22.59860000000...	60.66640000000...	12	20.00000000000...	36.00000000000...
240	Satakunta	21.45840000000...	61.98810000000...	80	240.0000000000...	400.0000000000...
241	Satakunta	22.52779999999...	62.08550000000...	9	27.00000000000...	27.00000000000...
242	Satakunta	22.28610000000...	61.97469999999...	9	21.60000000000...	21.60000000000...
243	Satakunta	21.55420000000...	61.95349999999...	12	36.00000000000...	36.00000000000...
244	Satakunta	21.47570000000...	61.93939999999...	36	60.00000000000...	180.0000000000...
245	Satakunta	21.47779999999...	61.86290000000...	1	2.000000000000...	3.000000000000...
246	Satakunta	21.72800000000...	61.83290000000...	8	26.00000000000...	26.00000000000...
247	Satakunta	21.57100000000...	61.76319999999...	9	27.00000000000...	27.00000000000...
248	Satakunta	21.25959999999...	61.60799999999...	30	90.00000000000...	160.0000000000...
249	Satakunta	21.37999999999...	61.63360000000...	7	13.30000000000...	13.30000000000...
250	Satakunta	21.45329999999...	61.60430000000...	2	1.300000000000...	1.300000000000...
251	Satakunta	21.50170000000...	61.59689999999...	2	12.00000000000...	12.00000000000...
252	Satakunta	21.51030000000...	61.61030000000...	5	5.000000000000...	5.000000000000...

253	Satakunta	21.67470000000...	61.63750000000...	12	54.00000000000...	54.00000000000...
254	Satakunta	21.62670000000...	61.45799999999...	9	16.00000000000...	27.00000000000...
255	Satakunta	21.60040000000...	61.30789999999...	8	16.00000000000...	24.00000000000...
256	Satakunta	21.56739999999...	61.35629999999...	8	16.00000000000...	24.00000000000...
257	Satakunta	21.59770000000...	61.40860000000...	31	109.0000000000...	165.0000000000...
258	Satakunta	22.77919999999...	61.21710000000...	2	3.600000000000...	3.600000000000...
259	Satakunta	22.79599999999...	61.14999999999...	1	0.100000000000...	0.100000000000...
260	Satakunta	21.50529999999...	61.13640000000...	3	9.000000000000...	9.000000000000...
261	Satakunta	22.75860000000...	61.12539999999...	8	24.00000000000...	24.00000000000...
262	Satakunta	23.24869999999...	60.89569999999...	4	10.00000000000...	NULL
263	Satakunta	21.54070000000...	61.14090000000...	12	18.00000000000...	36.00000000000...
264	Satakunta	21.47139999999...	61.12160000000...	4	8.000000000000...	8.000000000000...
265	Satakunta	21.44839999999...	61.10849999999...	2	2.000000000000...	6.000000000000...
266	Satakunta	21.66880000000...	61.22760000000...	2	2.000000000000...	2.000000000000...
267	Satakunta	21.59770000000...	61.40849999999...	null	80.00000000000...	90.00000000000...
268	Satakunta	21.68819999999...	61.68820000000...	10	10.00000000000...	30.00000000000...
269	Satakunta	21.54990000000...	61.54010000000...	7	14.00000000000...	21.00000000000...
270	Satakunta	21.52860000000...	61.59890000000...	6	18.00000000000...	18.00000000000...
271	Satakunta	21.64930000000...	61.63450000000...	12	24.00000000000...	36.00000000000...
272	Pirkanmaa	22.89630000000...	61.51070000000...	5	8.000000000000...	15.00000000000...
273	Pirkanmaa	22.89640000000...	61.51070000000...	2	3.000000000000...	3.000000000000...
274	Pirkanmaa	22.77750000000...	61.53670000000...	1	0.200000000000...	0.200000000000...
275	Pirkanmaa	22.70019999999...	61.30299999999...	1	0.200000000000...	0.200000000000...
276	Pirkanmaa	23.01259999999...	61.08630000000...	9	20.69999999999...	27.00000000000...
277	Pirkanmaa	24.26549999999...	62.01080000000...	1	0.600000000000...	0.600000000000...
278	Pirkanmaa	22.99579999999...	61.78199999999...	1	1.000000000000...	1.000000000000...
279	Pirkanmaa	24.10389999999...	61.43000000000...	1	3.000000000000...	3.000000000000...
280	Pirkanmaa	23.97860000000...	62.21640000000...	2	6.000000000000...	6.000000000000...
281	Pirkanmaa	24.07770000000...	61.76370000000...	5	10.00000000000...	15.00000000000...
282	Pirkanmaa	24.46089999999...	61.50070000000...	2	3.000000000000...	3.000000000000...
283	Tavastia_proper	23.36479999999...	60.99260000000...	20	46.00000000000...	66.00000000000...
284	Tavastia_proper	23.30989999999...	60.87539999999...	4	12.00000000000...	12.00000000000...
285	Tavastia_proper	23.65050000000...	60.70360000000...	10	23.00000000000...	32.00000000000...
286	P?ij?nne_Tavastia	25.57600000000...	60.83270000000...	6	18.00000000000...	20.00000000000...
287	P?ij?nne_Tavastia	25.86459999999...	61.73409999999...	3	6.000000000000...	9.000000000000...
288	Uusimaa	23.24410000000...	60.08579999999...	4	9.000000000000...	12.00000000000...
289	Uusimaa	23.20210000000...	59.90449999999...	3	3.000000000000...	6.000000000000...
290	Uusimaa	23.09440000000...	59.87409999999...	4	8.000000000000...	8.000000000000...
291	Uusimaa	23.84929999999...	59.98460000000...	1	2.000000000000...	2.000000000000...
292	Uusimaa	23.95840000000...	59.85589999999...	60	180.0000000000...	300.0000000000...
293	Uusimaa	26.07849999999...	60.58599999999...	4	12.00000000000...	12.00000000000...
294	Uusimaa	23.25690000000...	60.07050000000...	6	8.000000000000...	18.00000000000...
295	Uusimaa	23.21569999999...	59.88389999999...	6	12.00000000000...	18.00000000000...
296	Uusimaa	26.29799999999...	60.39909999999...	3	4.000000000000...	9.000000000000...
297	Uusimaa	25.19879999999...	60.56349999999...	1	3.000000000000...	3.000000000000...
298	Kymenlaakso	26.59489999999...	60.49340000000...	6	14.00000000000...	18.00000000000...

299	Kymenlaakso	26.65599999999...	60.44820000000...	9	27.00000000000...	27.00000000000...
300	Kymenlaakso	26.82359999999...	60.50860000000...	6	8.000000000000...	30.00000000000...
301	Kymenlaakso	26.88560000000...	60.42830000000...	2	5.000000000000...	5.000000000000...
302	Kymenlaakso	26.88589999999...	60.42969999999...	1	2.400000000000...	2.400000000000...
303	Kymenlaakso	26.88410000000...	60.42680000000...	1	1.000000000000...	1.000000000000...
304	Kymenlaakso	26.88820000000...	60.42490000000...	1	2.400000000000...	2.400000000000...
305	Kymenlaakso	26.95890000000...	60.46390000000...	4	6.000000000000...	12.00000000000...
306	Kymenlaakso	26.97500000000...	60.47769999999...	4	12.00000000000...	12.00000000000...
307	Kymenlaakso	26.94889999999...	60.48330000000...	4	12.00000000000...	12.00000000000...
308	Kymenlaakso	26.93550000000...	60.50310000000...	2	4.600000000000...	6.000000000000...
309	Kymenlaakso	27.07900000000...	60.54849999999...	4	8.000000000000...	8.000000000000...
310	Kymenlaakso	27.03940000000...	60.58279999999...	40	60.00000000000...	240.0000000000...
311	Kymenlaakso	27.13149999999...	60.53269999999...	4	12.00000000000...	12.00000000000...
312	Kymenlaakso	27.17299999999...	60.54800000000...	2	6.000000000000...	6.000000000000...
313	Kymenlaakso	27.61759999999...	60.58760000000...	6	18.00000000000...	18.00000000000...
314	Kymenlaakso	26.63609999999...	60.37200000000...	3	9.000000000000...	9.000000000000...
315	Kymenlaakso	26.74269999999...	60.53439999999...	6	27.00000000000...	27.00000000000...
316	Kymenlaakso	26.93819999999...	60.49100000000...	4	8.000000000000...	12.00000000000...
317	Kymenlaakso	26.94460000000...	60.49459999999...	4	12.00000000000...	12.00000000000...
318	Kymenlaakso	27.17020000000...	60.52649999999...	2	6.000000000000...	6.000000000000...
319	Kymenlaakso	27.46800000000...	60.47290000000...	20	40.00000000000...	60.00000000000...
320	Kymenlaakso	27.49869999999...	60.62939999999...	9	18.00000000000...	27.00000000000...
321	Kymenlaakso	27.29660000000...	60.61990000000...	9	18.00000000000...	27.00000000000...
322	Kymenlaakso	26.69450000000...	60.86489999999...	13	16.00000000000...	39.00000000000...
323	South_Karelia	28.48539999999...	61.45300000000...	9	27.00000000000...	27.00000000000...
324	South_Karelia	27.74860000000...	61.14950000000...	8	24.00000000000...	24.00000000000...
325	South_Karelia	28.39780000000...	61.09570000000...	7	21.00000000000...	21.00000000000...
326	Southern_Savonia	27.84760000000...	61.89399999999...	2	6.000000000000...	6.000000000000...
327	Southern_Savonia	27.27910000000...	61.47149999999...	2	4.000000000000...	6.000000000000...
328	Southern_Savonia	29.26249999999...	62.22679999999...	9	27.00000000000...	27.00000000000...
329	Southern_Savonia	28.09789999999...	62.35380000000...	3	14.00000000000...	14.00000000000...
330	North_Karelia	28.91789999999...	63.40390000000...	9	25.00000000000...	30.00000000000...
331	North_Karelia	29.97500000000...	62.82560000000...	8	18.00000000000...	24.00000000000...
332	North_Karelia	30.21979999999...	63.10750000000...	7	21.00000000000...	21.00000000000...
333	NOrth_Savonia	28.09789999999...	62.35380000000...	3	14.00000000000...	14.00000000000...
334	NOrth_Savonia	27.98000000000...	63.11999999999...	8	24.00000000000...	24.00000000000...
335	NOrth_Savonia	27.98030000000...	63.31550000000...	13	39.00000000000...	39.00000000000...
336	Aland	20.95149999999...	59.94380000000...	1	0.500000000000...	0.500000000000...
337	Aland	20.67070000000...	60.11520000000...	1	0.700000000000...	0.700000000000...
338	Aland	20.39669999999...	60.22610000000...	1	0.500000000000...	0.500000000000...
339	Aland	20.24500000000...	60.10170000000...	1	0.600000000000...	0.600000000000...
340	Aland	20.31040000000...	59.99369999999...	1	0.600000000000...	0.600000000000...
341	Aland	19.95430000000...	59.96730000000...	1	2.300000000000...	2.300000000000...
342	Aland	20.02230000000...	60.07840000000...	1	0.600000000000...	0.600000000000...
343	Aland	19.68420000000...	60.11860000000...	8	18.00000000000...	28.00000000000...
344	Aland	19.57740000000...	60.14390000000...	6	18.00000000000...	18.00000000000...

322	Kymenlaakso	26.69450000000...	60.86489999999...	13	16.00000000000...	39.00000000000...
323	South_Karelia	28.48539999999...	61.45300000000...	9	27.00000000000...	27.00000000000...
324	South_Karelia	27.74860000000...	61.14950000000...	8	24.00000000000...	24.00000000000...
325	South_Karelia	28.39780000000...	61.09570000000...	7	21.00000000000...	21.00000000000...
326	Southern_Savonia	27.84760000000...	61.89399999999...	2	6.000000000000...	6.000000000000...
327	Southern_Savonia	27.27910000000...	61.47149999999...	2	4.000000000000...	6.000000000000...
328	Southern_Savonia	29.26249999999...	62.22679999999...	9	27.00000000000...	27.00000000000...
329	Southern_Savonia	28.09789999999...	62.35380000000...	3	14.00000000000...	14.00000000000...
330	North_Karelia	28.91789999999...	63.40390000000...	9	25.00000000000...	30.00000000000...
331	North_Karelia	29.97500000000...	62.82560000000...	8	18.00000000000...	24.00000000000...
332	North_Karelia	30.21979999999...	63.10750000000...	7	21.00000000000...	21.00000000000...
333	NOrth_Savonia	28.09789999999...	62.35380000000...	3	14.00000000000...	14.00000000000...
334	NOrth_Savonia	27.98000000000...	63.11999999999...	8	24.00000000000...	24.00000000000...
335	NOrth_Savonia	27.98030000000...	63.31550000000...	13	39.00000000000...	39.00000000000...
336	Aland	20.95149999999...	59.94380000000...	1	0.500000000000...	0.500000000000...
337	Aland	20.67070000000...	60.11520000000...	1	0.700000000000...	0.700000000000...
338	Aland	20.39669999999...	60.22610000000...	1	0.500000000000...	0.500000000000...
339	Aland	20.24500000000...	60.10170000000...	1	0.600000000000...	0.600000000000...
340	Aland	20.31040000000...	59.93369999999...	1	0.600000000000...	0.600000000000...
341	Aland	19.95430000000...	59.96730000000...	1	2.300000000000...	2.300000000000...
342	Aland	20.02230000000...	60.07840000000...	1	0.600000000000...	0.600000000000...
343	Aland	19.68420000000...	60.11860000000...	8	18.00000000000...	28.00000000000...
344	Aland	19.57740000000...	60.14390000000...	6	18.00000000000...	18.00000000000...
345	Aland	19.52520000000...	60.18189999999...	1	0.200000000000...	0.200000000000...
346	Aland	19.49820000000...	60.24819999999...	1	0.500000000000...	0.500000000000...
347	Aland	19.97319999999...	60.36410000000...	1	0.500000000000...	0.500000000000...
348	Aland	19.96730000000...	60.36359999999...	1	0.500000000000...	0.500000000000...
349	Aland	19.97909999999...	60.36450000000...	1	0.600000000000...	0.600000000000...
350	Aland	20.15319999999...	60.24040000000...	42	81.00000000000...	105.0000000000...
351	Aland	20.30000000000...	59.99210000000...	6	18.00000000000...	21.00000000000...
352	Aland	20.24390000000...	60.10499999999...	1	0.600000000000...	0.600000000000...
353	Aland	19.95420000000...	59.95879999999...	1	2.300000000000...	2.300000000000...
354	Aland	19.94980000000...	59.96459999999...	1	2.300000000000...	2.300000000000...
355	Aland	19.95430000000...	59.96730000000...	1	2.300000000000...	2.300000000000...
356	Aland	19.95810000000...	59.96490000000...	1	2.300000000000...	2.300000000000...
357	Aland	19.96849999999...	59.96500000000...	1	2.300000000000...	2.300000000000...
358	Aland	19.96780000000...	59.96220000000...	1	2.300000000000...	2.300000000000...
359	Aland	20.02540000000...	60.07790000000...	1	0.600000000000...	0.600000000000...
360	Aland	20.02479999999...	60.08050000000...	1	0.600000000000...	0.600000000000...
361	Aland	20.02760000000...	60.08019999999...	1	0.600000000000...	0.600000000000...

The table above represents all the sites in (text, figurer 1) with their location, number of turbines and nominal minimum and maximum power in mega Watts.

Table 2 Regional wind power in MW

NAME_2	VARNAME_2	Windpower
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	3428.700
Ostrobothnia	Österbotten|Pohjanmaa	2028.500
Lapland	Lappi|Lappland	1092.500
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	1024.400
Satakunta	Satakunta|Satakunda	994.900
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	990.000
Finland Proper	Varsinais-Suomi|Egentliga Finland	830.000
Central Finland	Keski-Suomi|Mellersta Finland	464.700
Kymenlaakso	Kymenlaakso|Kymmenedalen	352.400
Uusimaa	Itä-Uusimaa|Östra Nyland	241.000
Kainuu	Kainuu|Kajanaland	138.000
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	82.000
North Savonia	Pohjois-Savo|Norra Savolax	77.000
South Karelia	Etelä-Karjala|Södra Karelen	72.000
North Karelia	Pohjois-Karjala|Norra Karelen	64.000
Pirkanmaa	Pirkanmaa|Birkaland	55.700
Southern Savonia	Etelä-Savo|Södra Savolax	51.000
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	24.000
Åland	Åland Islands	159.300

Table 3 the total energy in PJ, TCE, Hh's

NAME_2	VARNAME_2	WP_PJ	WP_TCE	WP_HH's
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	22.61296224	1234442.9	339901
Ostrobothnia	Österbotten|Pohjanmaa	13.37836320	730328.0	201082
Lapland	Lappi|Lappland	7.20525600	393268.6	108279
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	6.75612288	368898.2	101569
Satakunta	Satakunta|Satakunda	6.56156448	358285.2	98647
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	6.52924800	356516.4	98160
Finland Proper	Varsinais-Suomi|Egentliga Finland	5.47401600	298931.3	82305
Central Finland	Keski-Suomi|Mellersta Finland	3.06478944	167252.2	46049
Kymenlaakso	Kymenlaakso|Kymmenedalen	2.32414848	12692.3	34956
Uusimaa	Uusimaa|Nyland	1.58944320	86868.9	23917
Kainuu	Kainuu|Kajanaland	0.91013760	49723.6	13690
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.54080640	29480.4	8117
North Savonia	Pohjois-Savo|Norra Savolax	0.50783040	27711.6	7629
South Karelia	Etelä-Karjala|Södra Karelen	0.47485440	25942.8	7142
North Karelia	Pohjois-Karjala|Norra Karelen	0.42209280	22994.7	6331
Pirkanmaa	Pirkanmaa|Birkaland	0.36735264	20046.7	5519
Southern Savonia	Etelä-Savo|Södra Savolax	0.33635520	18277.9	5032
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.15828480	8647.6	2380
Åland	Åland Islands	1.137643200	62107.75080	15743

The table above represents the total energy for each region in petajoules (PJ), tons of coal equivalent (TCE), and the amount of energy that each regions potential wind power can provide energy for an average sized households (Hh's). These values are shown in figure 2 in the text.

In calculating the amount of energy that each region has potentially I used the sum of each regions minimum power. I used an average of 1 832 hours per year of nominal wind power to calculate the amount of energy produced. This value was calculated from a time span of seven years from 2007 to 2013, by dividing the amount of energy produced each year by the amount of power capacity.

Table 4 the actual production of wind power from 2007 to 2014

Tuulivoima Suomessa.[1]		
Vuosi	MW	GWh
2007	109	188
2008	142	261
2009	146	277
2010	196	294
2011	198[1] (199)[3]	481
2012	257[1] (288)[3]	494
2013	447[1] (448)[4]	777[1][4]
2014	627[5][6]	1112[5]

Calculation example:

For example the total power of North Ostrobothnia is 3428.7 MW which converted to potential renewable energy is $3428.7 \times 10^6 W \times 1832 h\ per\ year$ = 6.2813784 × $10^{12}\ Wh \approx 6.28\ TWh\ per\ year$. Since 1 TWh equals 3.6 PJ then converting to petajoules is: 6.2813784 × 3.6 = 22.61944224 $PJ\ per\ year$. In calculating the tonne of coal equivalent (hard coal) I took into consideration that an electrical power plant in general has 40% efficiency in producing energy. 1 *terawatt hour* = 122 835.032 55 *tons of coal equivalent*, this leads to: 6.2813784 × 122835.032 × 1.6 = 1234442.9 $TCE.$ The units of households was calculated by using the value of a typical Finnish household (120 m^2) that uses electricity in a year which is 18480 kWh per year. Then follows that: $\frac{6.2813784 \times 10^{12} Wh}{18480 \times 10^3 Wh\ per\ Hh's}$ = 339 9

Figures, tables and calculations for potential solar power

Global formula : **E = A * r * H * PR**

E = Energy (kWh)	386770643	kWh/an
A = Total solar panel Area (m²)	3022892	m²
r = solar panel yield (%)	15 %	
H = Annual average irradiation on tilted panels (shadings not included)*	1138	kWh/m².an
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)	0.75	
Total power of the system	453433.8	kWp

Losses details (depend of site, technology, and sizing of the system)

- Inverter losses (6% to 15 %)	8 %
- Température losses (5% to 15%)	8 %
- DC cables losses (1 to 3 %)	2 %
- AC cables losses (1 to 3 %)	2 %
- Shadings 0 % to 40% (depends of site)	3 %
- Losses weak irradiation 3% yo 7%	3 %
- Losses due to dust, snow... (2%)	2 %
- Other Losses	0 %

Figure 2 an example of how to calculate the photovoltaic output [11]

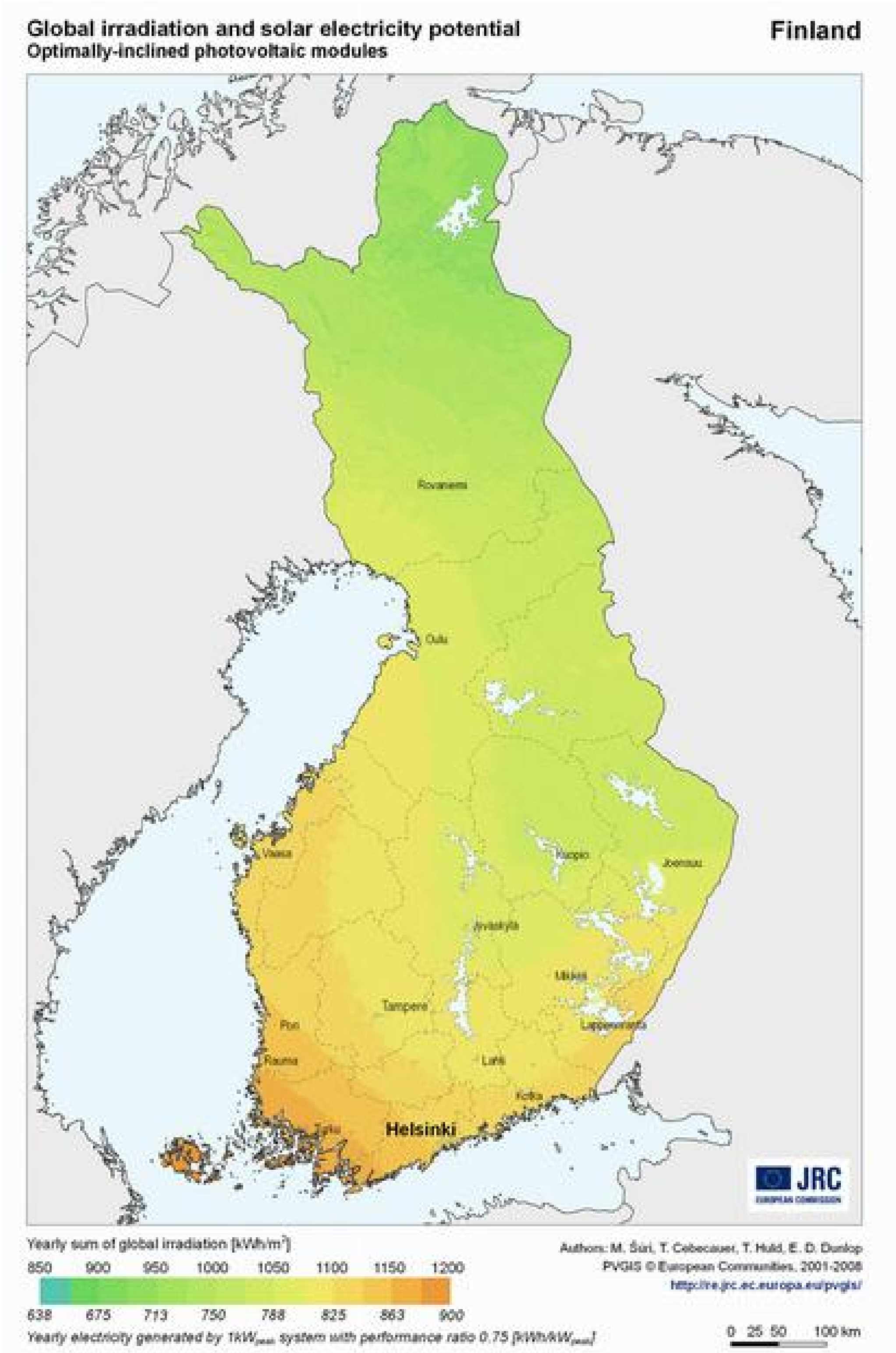


Figure 3 irradiation of Finland (PVGIS-solar-optimum-FI.png | Open Ener y Information. 2015)

Table 5 total capacity regionally in MW

NAME_2	VARNAME_2	Solar Po.
Uusimaa	Itä-Uusimaa|Östra Nyland	452.717
Finland Proper	Varsinais-Suomi|Egentliga Finland	345.904
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	211.300
Pirkanmaa	Pirkanmaa|Birkaland	210.926
Satakunta	Satakunta|Satakunda	142.293
Central Finland	Keski-Suomi|Mellersta Finland	137.382
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	135.435
North Savonia	Pohjois-Savo|Norra Savolax	126.454
Lapland	Lappi|Lappland	111.107
Ostrobothnia	Österbotten|Pohjanmaa	106.058
Kymenlaakso	Kymenlaakso|Kymmenedalen	96.355
North Karelia	Pohjois-Karjala|Norra Karelen	95.771
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	92.365
Southern Savonia	Etelä-Savo|Södra Savolax	91.921
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	91.280
South Karelia	Etelä-Karjala|Södra Karelen	72.046
Kainuu	Kainuu|Kajanaland	48.485
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	21.584
Åland	Åland Islands	20.815

The table above shows the total power each region has from solar power in MW.

Table 6 Power converted to PJ,TCE and Hh's

NAME_2	VARNAME_2	SP_PJ	SP_TCE	SP_Hhs
Uusimaa	Uusimaa|Nyland	2.9010105360	158375.877200	43606.0
Finland Proper	Varsinais-Suomi|Egentliga Finland	2.4780562560	135285.387100	37248.0
Pirkanmaa	Pirkanmaa|Birkaland	1.3516138080	73789.122710	20316.0
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	1.2123583200	72258.837980	19895.0
Satakunta	Satakunta|Satakunda	0.8913223352	48660.325760	13398.0
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	0.8483648400	46315.076770	12752.0
Central Finland	Keski-Suomi|Mellersta Finland	0.7903311696	43146.824420	11880.0
North Savonia	Pohjois-Savo|Norra Savolax	0.7274645712	39714.726350	10935.0
Ostrobothnia	Österbotten|Pohjanmaa	0.6643473120	36268.944360	9985.0
Lapland	Lappi|Lappland	0.6199770600	39714.726350	9319.0
Kymenlaakso	Kymenlaakso|Kymmenedalen	0.6174428400	33708.271710	9281.0
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.5918749200	20195.270851	8897.0
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.5849222400	31932.863280	8792.0
North Karelia	Pohjois-Karjala|Norra Karelen	0.5509514088	30078.281880	8281.0
Southern Savonia	Etelä-Savo|Södra Savolax	0.5288031288	28869.133130	7949.0
South Karelia	Etelä-Karjala|Södra Karelen	0.4144662288	22627.098980	6230.0
Kainuu	Kainuu|Kajanaland	0.2789245080	15227.422680	4192.0
Åland	Åland Islands llersta Österbotten	0.149118660	8140.886860	2241

The table above shows each region how much energy would be produced in PJ, the amount of tons of coal equivalent would be saved and the amount of households the energy would be used for a year.

Calculation example:
The calculated power for Pirkanmaa is 210.926 MW.
The average annual sunlight that Pirkanmaa has in a year is 1780 hours (see below the chart on annual sunlight per region).
1780 h × 210.926 MW = 3.7544828×10^{11} Wh ≈ 0.375 TWh
3.7544828×10^{11} Wh × 3 600 J/Wh = $1.351613808 \times 10^{15}$ J ≈ 1.352 PJ
0.375 TWh × 122835.03255 TCE/TWh = 46118.201695 TCE
46118.201695 TCE × 1.6 (a power plant with an efficiency of 40 %) = 73789.12271 TCE
3.7544828×10^{11} Wh / 18480×10^{3} Wh/Hhs = 20316 Hhs

Table 6 the amount of sunlight that some regions have.

Mittausasema	Tammi	Helmi	Maalis	Huhti	Touko	Kesä	Heinä	Elo	Syys	Loka	Marras	Joulu	Vuosi
Parainen (Utö)	39	66	138	211	309	308	321	259	179	95	39	26	1 990
Vantaa (Helsinki-Vantaan lentoasema)	38	74	131	196	275	266	291	219	143	84	37	26	1 780
Jyväskylä (Jyväskylän lentoasema)	29	73	126	187	256	247	263	199	120	59	25	14	1 598
Oulu (Oulun lentoasema)	24	69	137	208	273	296	283	212	133	69	28	8	1 740
Rovaniemi (Rovaniemen lentoasema)	15	57	132	203	237	271	260	182	112	60	18	3	1 550
Utsjoki (Kevo)	4	48	123	185	192	220	209	133	89	50	10	0	1 263

(Wikipedia- Suomen ilamsto)

The table above shows six different measuring stations throughout the country. It shows the amount of sunshine each station received throughout the year starting from January until December and the accumulative year.

Figures, tables and calculations for potential bioenergy

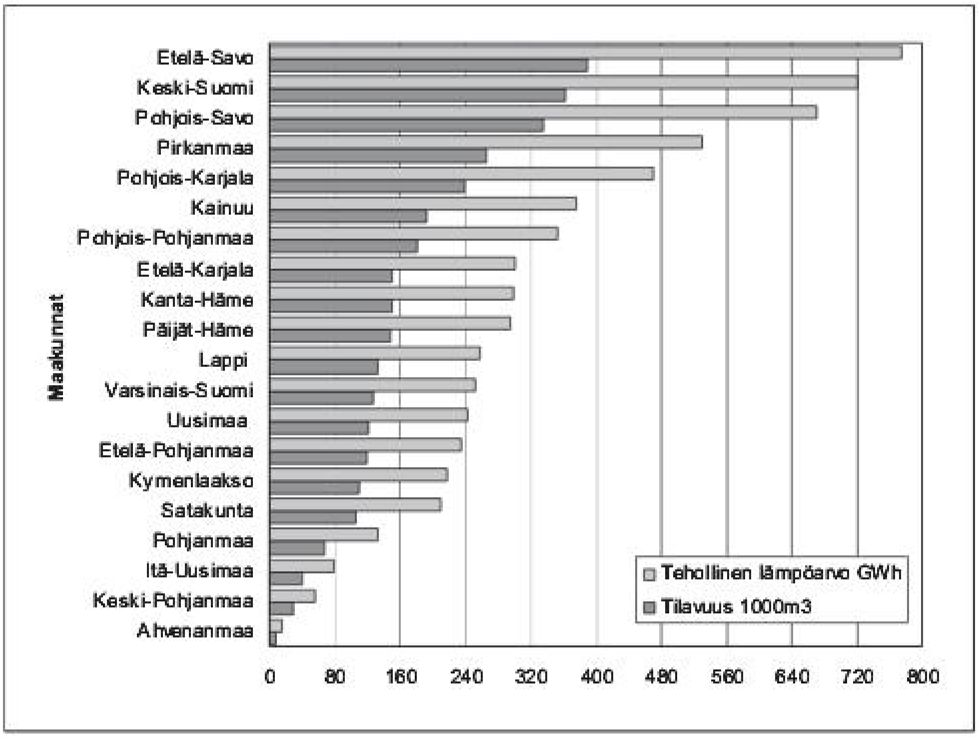


Figure 4 technical achievable lumber

The chart above represents the annual technically achievable lumber residue potential by region. Light grey is the nominal energy in GWh and dark grey represents the volume in m^3. (Ranta 2002; Hakkila 2004).

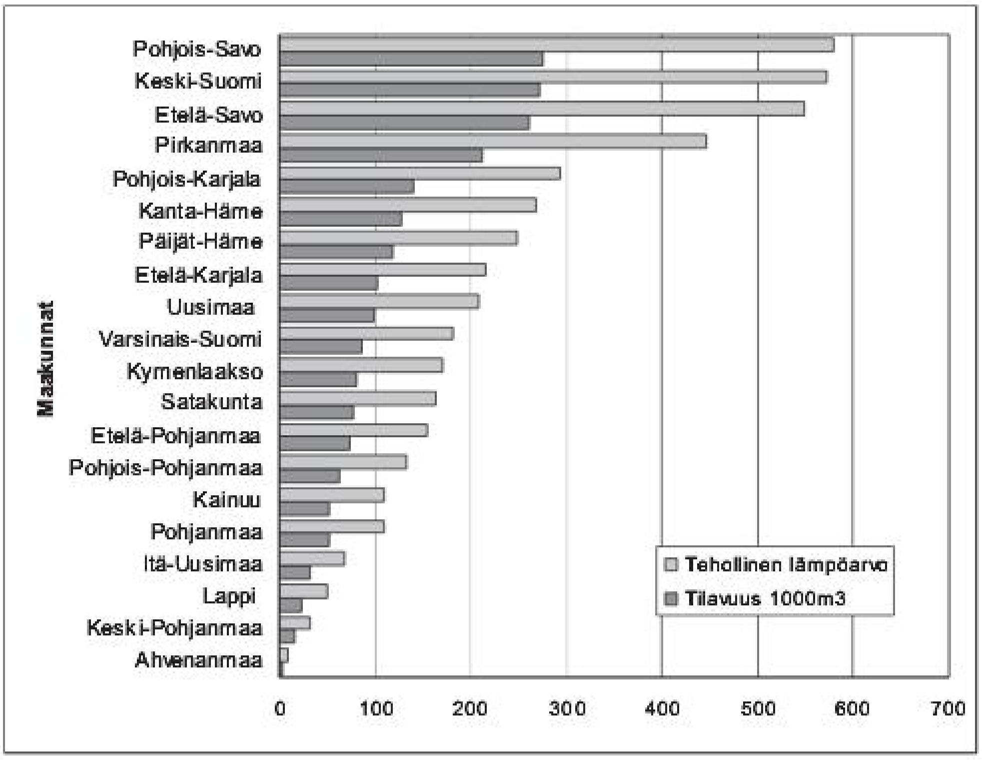


Figure 5 technical achievable stumps from forest industry

The chart above represents the technical potential for gathering the stumps from the forest industry by region. Light grey is the nominal energy in GWh and dark grey represents the volume in m^3. (Hakkila 2004, Helynen ym. 2007).

Calculations:

It was taken that the moisture of the wood chips wood be 55 %. The energy values of wood chips are: pine= 1.9 MWh/ m^3, spruce= 2.0 MWh/ m^3 and the deciduous trees = 2.3 MWh/ m^3. The average is 2.07 MWh/ m^3.

For example South Savonia:

Woodchips from lumber biomass:

776 GWh/a / 8760 h/a = 88.584 MW

Woodchips from management of nursery trees:

1180 GWh/a / 8760 h/a = 134.703 MW

Woodchips from trunk residual:

550 GWh/a / 8760 h/a = 62.785 MW

The total power:

(88.584 + 134.703 + 62.785) MW = 286.072 MW

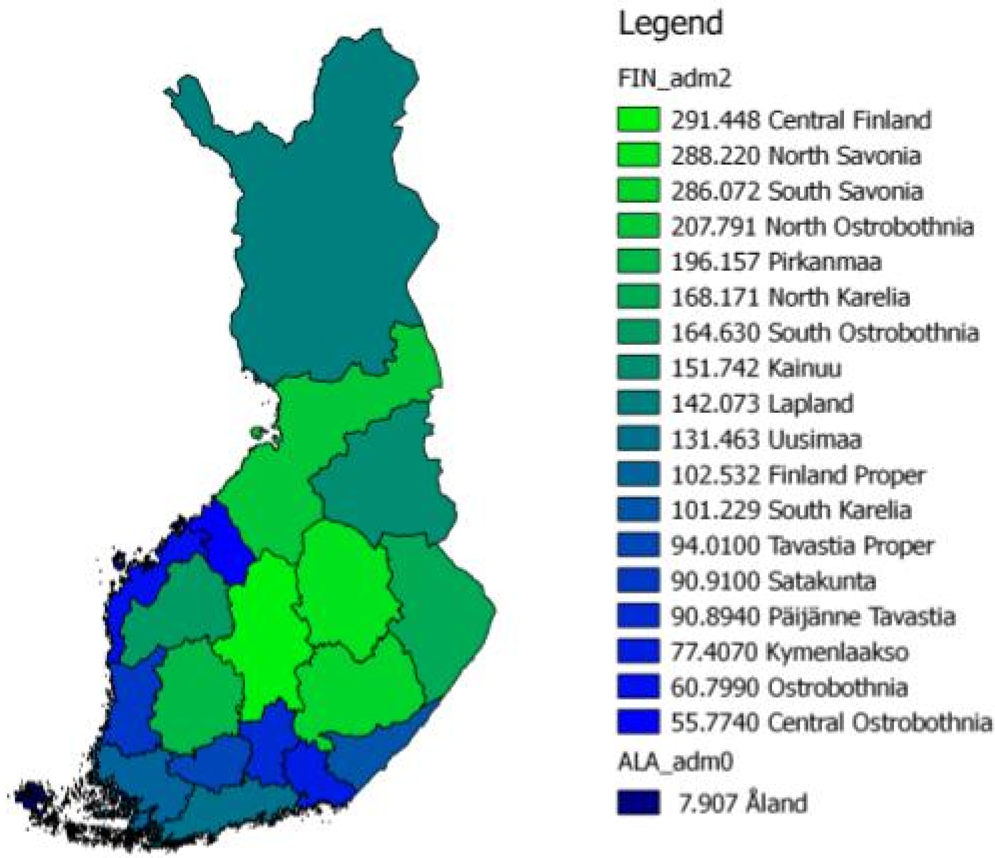


Figure 6 shows the total potential of bioenergy in MW.

Table 7 Bioenergy per region in MW

NAME_2	VARNAME_2	Biofuels
Central Finland	Keski-Suomi|Mellersta Finland	291.448
North Savonia	Pohjois-Savo|Norra Savolax	288.220
Southern Savonia	Etelä-Savo|Södra Savolax	286.072
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	207.791
Pirkanmaa	Pirkanmaa|Birkaland	196.157
North Karelia	Pohjois-Karjala|Norra Karelen	168.171
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	164.630
Kainuu	Kainuu|Kajanaland	151.742
Lapland	Lappi|Lappland	142.073
Uusimaa	Itä-Uusimaa|Östra Nyland	131.463
Finland Proper	Varsinais-Suomi|Egentliga Finland	102.532
South Karelia	Etelä-Karjala|Södra Karelen	101.229
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	94.010
Satakunta	Satakunta|Satakunda	90.910
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	90.894
Kymenlaakso	Kymenlaakso|Kymmenedalen	77.407
Ostrobothnia	Österbotten|Pohjanmaa	60.799
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	55.774

Table 8 MW converted to PJ, TCE and Hh's

NAME_2	VARNAME_2	BF_PJ	BF_TCE	BF_Hhs
Central Finland	Keski-Suomi|Mellersta Finland	9.1923655680	501842.01060	138173.0
North Savonia	Pohjois-Savo|Norra Savolax	9.0893059200	496215.63940	136624.0
Southern Savonia	Etelä-Savo|Södra Savolax	9.0215665920	492517.52270	135606.0
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	6.5528969760	223590.36482	98498.0
Pirkanmaa	Pirkanmaa|Birkaland	6.1860071520	337714.84000	92984.0
North Karelia	Pohjois-Karjala|Norra Karelen	5.3034406560	289532.58030	79717.0
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	5.1917716800	283436.19700	78039.0
Kainuu	Kainuu|Kajanaland	4.7853357120	163279.68554	71930.0
Lapland	Lappi|Lappland	4.4804141280	244600.80680	67346.0
Uusimaa	Uusimaa|Nyland	4.1458170000	226334.03860	62317.0
Finland Proper	Varsinais-Suomi|Egentliga Finland	3.2334491520	176524.81410	48603.0
South Karelia	Etelä-Karjala|Södra Karelen	3.1923577440	174281.49660	47985.0
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	2.9646993600	161852.86330	44563.0
Satakunta	Satakunta|Satakunda	2.8669377600	156515.73030	43094.0
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	2.8664331840	156488.18380	43086.0
Kymenlaakso	Kymenlaakso|Kymmenedalen	2.4411071520	133268.21180	36693.0
Ostrobothnia	Österbotten|Pohjanmaa	1.9173572640	104674.95200	28820.0
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	1.7588888640	96023.63149	26438.0
Åland	Åland Islands	0.02493510	13613.13254	3748

The table above shows the values that each region would produce biofuel energy per year. The units are in petajoules (PJ), tons in coal equivalent (TCE) and households (Hh’s).

Calculation example for South Savonia:

286.072 MW × 8760h = 2.50599072 TWh

2.50599072 TWh × 3600 PJ/TWh = 9.021566592 PJ

9.021566592 PJ × 34 120.842 375 TCE/PJ = 307 823.4517 TCE

307 823.4517 TCE × 1.6 (efficiency of a power plant with 40%) = 492 517.5227 TCE

2.50599072 TWh / 18480 kWh/Hh’s = 135 605 Hh’s

Tables and calculation for potential geothermal heat pumps

Calculation:

$\dot{W}_{net,in}$ = is the power needed to run the heat pump

$\dot{Q}_H$= magnitude of heat transfer between the cyclic device (in this case heat pump) and the high temperature medium at temperature $T_{H.}$

$\dot{Q}_L$= magnitude of heat transfer between the cyclic device (in this case the heat pump) and the low temperature medium at temperature T_L.

COP_{HP} = coefficient of performance of the heat pump, in this case it is 2.9.

$\dot{W}_{net,in} = \dot{Q}_H / COP_{HP}$; the power consumed by the heat pump

$\dot{Q}_L = \dot{Q}_H - \dot{W}_{net,in}$; the rate of absorption from the surrounding

The assumption is that by 2020 6 % of the detached houses in each region would have installed a heat pump.

Example:

The region Uusimaa has 188 523 detached households 6 per cent of 188 523 is:

188 523 × 0.06 = 11311 households.

The average household has an area of 120 m^2 with an average of 13200 kWh/a.

13200 kWh/annum × 1 annum/8760 h = 1.507 kW

$\dot{Q}_H$ = 1.507 kJ/s × 3600 s/h = 5425.2 kJ/h

$\dot{W}_{net,in} = \dot{Q}_H / COP_{HP} = \frac{5425.2\ kJ/h}{2.9}$ = 1870.76 kJ/h

1870.76 kJ/h × 1h/3600 s = 0.520 kW

0.520 kW × 8760 h/annum = 4555.2 kWh/annum

$\dot{Q}_L = \dot{Q}_H - \dot{W}_{net,in}$ = 13200 kWh/annum – 45552 kWh/ annum= 8644 kWh/annum

8644.8 kWh/annum × 1 annum/8760 h = 0.9868 kW

0.9868 kW × 11311 = 11161.7 kW = 11.161 MW

This is how much power in theory would be taken out of the surrounding that a 6 % of the households would install heat pumps by 2020. The rest of the regions can be seen in the table below.

Table 9 power absorbed from surrounding to heat pumps

NAME_2	VARNAME_2	Geothermal
Uusimaa	Itä-Uusimaa|Östra Nyland	11.162
Finland Proper	Varsinais-Suomi|Egentliga Finland	5.288
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	5.217
Pirkanmaa	Pirkanmaa|Birkaland	5.195
Satakunta	Satakunta|Satakunda	3.560
North Savonia	Pohjois-Savo|Norra Savolax	3.397
Central Finland	Keski-Suomi|Mellersta Finland	3.390
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	3.249
Lapland	Lappi|Lappland	2.791
Ostrobothnia	Österbotten|Pohjanmaa	2.597
Kymenlaakso	Kymenlaakso|Kymmenedalen	2.478
North Karelia	Pohjois-Karjala|Norra Karelen	2.453
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	2.330
Southern Savonia	Etelä-Savo|Södra Savolax	2.248
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	2.214
South Karelia	Etelä-Karjala|Södra Karelen	1.874
Kainuu	Kainuu|Kajanaland	1.199
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	1.092
Åland	Åland Islands	0.503

The table above represents the power that is absorbed from the surrounding to the heat pumps in MW.

Conversion of units from MW to PJ, Tons of Oil Equivalent (TOE) and Households (Hhs). Uusimaa will be used as an example:

11.162 MW × 8760 h = 0.09777912 TWh = 0.352004832 PJ.

0.09777912 TWh/ 18480 kWh per household in a year= 5291 Hh’s

The average efficiency of an oil fired power plant is 80 %.

1 petajoule = 23 884.589 663 tonne of oil equivalent.

0.352004832 × 23 884.589 663 × 1.2= 10088.98917 TOE.

The table below represents the rest of the values that were calculated in the same manner.

Table 10 represents energy in PJ, TOE and households for each region.

NAME_2	VARNAME_2	GTHP_PJ	GTHP_TOE	GTHP_Hhs
Uusimaa	Uusimaa|Nyland	0.3520048320	10088.9891700	5291.0
Finland Proper	Varsinais-Suomi|Egentliga Finland	0.1667623680	4779.6608770	2506.0
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	0.1645233120	4715.4861570	2473.0
Pirkanmaa	Pirkanmaa|Birkaland	0.1638295200	4695.6010300	2463.0
Satakunta	Satakunta|Satakunda	0.1122681600	3217.7747210	1688.0
North Savonia	Pohjois-Savo|Norra Savolax	0.1071277920	3064.1169390	1610.0
Central Finland	Keski-Suomi|Mellersta Finland	0.1069070400	3064.1169390	1607.0
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	0.1024604640	2936.6713670	1540.0
Lapland	Lappi|Lappland	0.0880169760	3363.5989680	1323.0
Ostrobothnia	Österbotten|Pohjanmaa	0.0818989920	2347.3485810	1231.0
Kymenlaakso	Kymenlaakso|Kymmenedalen	0.0781462080	2239.7881340	1175.0
North Karelia	Pohjois-Karjala|Norra Karelen	0.0773578080	2217.1914020	1163.0
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.0734788800	2808.0206360	1104.0
Southern Savonia	Etelä-Savo|Södra Savolax	0.0708929928	2031.8981940	1066.0
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.0698207040	2001.1666380	1049.0
South Karelia	Etelä-Karjala|Södra Karelen	0.0590984640	1693.8510750	888.0
Kainuu	Kainuu|Kajanaland	0.0378116640	1084.7392950	568.0
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	0.0344373120	987.0252795	518.0
Åland	Åland Islands	0.015862600	454.6462597	238

Figures, tables and calculations for hydropower

Table 11 Hydropower plants in Finland (Oy vesirakentaja, Suomen vesivoimalaitokset)

Vesistö / River basin	Vesistö / River basin	Voimalaitos / Power plant	Voimalaitos / Power plant	Putous / Head (m)	Teho / Power (MW)	Energia / Energy (GWh/a)
1	Jänisjoki	1	Vääräkoski	7,5	1,8	8,5
1	Jänisjoki	2	Saario	6,5	1,6	6,3
1	Jänisjoki	3	Vihtakoski	8,3	1,4	6,9
1	Jänisjoki	4	Ruskeakoski	20	3,2	15
3	Hiitolanjoki	1	Kangaskoski	6,0	1,0	3,3
3	Hiitolanjoki	2	Lahnasenkoski	8,0	0,8	4,5
3	Hiitolanjoki	3	Ritakoski	6,0	0,4	2,2
3	Hiitolanjoki	4	Juvankoski	7,0	0,8	4,4
4	Vuoksi	1	Imatra	25	178	1000
4	Vuoksi	2	Tainionkoski	8,0	62	300
4	Vuoksi	3	Liuna	6,5	1,1	4,6
4	Vuoksi	4	Maavesi	10	1,9	5,5
4	Vuoksi	5	Huruskoski	4,7	4,4	28
4	Vuoksi	6	Ylä-Sorsa	9,0	0,5	2,2
4	Vuoksi	7	Ala-Sorsa	11	0,8	3,2
4	Vuoksi	8	Puhos	3,7	0,8	1,5
4	Vuoksi	9	Puntarikoski	12	6,0	11
4	Vuoksi	10	Kuurna	6,9	18	115
4	Vuoksi	11	Kaltimo	10	24	155
4	Vuoksi	12	Pamilo	50	84	256
4	Vuoksi	13	Lieksankoski	12	16	75
4	Vuoksi	14	Pankakoski	11	15	65
4	Vuoksi	15	Kuokkastenkoski	10	1,8	5,0
4	Vuoksi	16	Louhikoski	11	0,5	2,2
4	Vuoksi	17	Palokki	21	7,4	30
4	Vuoksi	18	Karjalankoski	6,5	6,0	23
4	Vuoksi	19	Juankoski	6,5	5,5	21
4	Vuoksi	20	Atro	15	6,5	18
4	Vuoksi	21	Sälevä	7,0	3,0	6,5
4	Vuoksi	22	Kiltua	19	5,6	7,5
4	Vuoksi	23	Viannankoski	2,5	0,2	1,3
4	Vuoksi	24	Salahmi	13	0,8	3,0
4	Vuoksi	25	Pitkäkoski	7,4	0,1	0,5
11	Virojoki	1	Kantturakoski	6,0	0,4	1,5
11	Virojoki	2	Pitkäkoski	8,0	0,2	1,0

14	Kymijoki	1	Ahvenkoski	11	24	120
14	Kymijoki	2	Klåsarö	3,5	5,0	34
14	Kymijoki	3	Ediskoski	9,1	0,5	3,0
14	Kymijoki	4	Koivukoski	4,5	1,5	9,0
14	Kymijoki	5	Korkeakoski	13	10	57
14	Kymijoki	6	Inkeroinen	9,7	17	80
14	Kymijoki	7	Anjalankoski	9,7	20	130
14	Kymijoki	8	Myllykoski 1&2	7,0	29	150
14	Kymijoki	9	Keltti	6,	17	125
14	Kymijoki	10	Kuusankoski	9,2	30	180
14	Kymijoki	11	Voikkaa	9,0	29	170
14	Kymijoki	12	Mankala	8,0	25	130
14	Kymijoki	13	Vuolenkoski	3,3	8,3	50
14	Kymijoki	14	Tirva	4,4	0,2	1,3
14	Kymijoki	15	Kannuskoski	4,6	0,3	1,4
14	Kymijoki	16	Arrakoski	20	0,5	1,7
14	Kymijoki	17	Verla 1&2	6,2	3,1	15
14	Kymijoki	18	Siikakoski	3,5	2,0	9,0
14	Kymijoki	19	Voikoski	2,5	0,3	2,0
14	Kymijoki	20	Kissakoski	5,0	1,6	9,0
14	Kymijoki	21	Virtaankoski	4,5	0,6	3,4
14	Kymijoki	22	Patala	13	2,4	8,3
14	Kymijoki	23	Rekola	6,0	0,5	2,0
14	Kymijoki	24	Kalliokoski	5,5	0,5	2,0
14	Kymijoki	25	Koskensaarenkoski	22	0,6	1,0
14	Kymijoki	26	Kangaskoski	4,4	0,6	2,3
14	Kymijoki	27	Puuppolankoski	16	0,4	1,0
14	Kymijoki	28	Vaajakoski	2,0	3,5	20
14	Kymijoki	29	Kuhankoski	3,5	3,4	25
14	Kymijoki	30	Äänekoski	8,0	5,5	30
14	Kymijoki	31	Hietama	14	7,2	26
14	Kymijoki	32	Parantalankoski	13	1,2	3,0
14	Kymijoki	33	Leuhunkoski	9,0	3,2	11
14	Kymijoki	34	Venekoski	5,6	0,3	1,4
14	Kymijoki	35	Kellankoski	2,0	0,2	1,5
14	Kymijoki	36	Haapakoski	6,5	0,2	0,6
14	Kymijoki	37	Huopanankoski	7,3	0,3	1,2
14	Kymijoki	38	Hilmo	24	6,0	28
14	Kymijoki	39	Laukaan Myllykoski	15	0,2	1,7
14	Kymijoki	40	Tourujoki	11	0,6	1,5
18	Porvoonjoki	1	Strömsberg	11	0,9	2,0
18	Porvoonjoki	2	Vakkola	9,0	0,6	1,0

18	Porvoonjoki	3	Naarkoski	7,5	0,8	3,0
18	Porvoonjoki	4	Tönnönkoski	4,5	0,1	0,8
18	Porvoonjoki	5	Vääräkoski	3,9	0,1	0,4
19	Mustijoki	1	Tjusterby	3,5	0,2	1,4
19	Mustijoki	2	Laukkoski	5,7	0,1	0,5
19	Mustijoki	3	Lahankoski	10	0,5	2,2
19	Mustijoki	4	Halkiankoski	10	0,3	1,5
21	Vantaa	1	Vanhakaupunki	6,1	0,1	0,9
23	Karjaanjoki	1	Åminnefors	5,0	1,0	5,5
23	Karjaanjoki	2	Billnäs	7,0	1,4	6,5
23	Karjaanjoki	3	Peltokoski	11	2,3	11
23	Karjaanjoki	4	Mustio	8,0	1,8	7,0
23	Karjaanjoki	5	Nahkionkoski	9,5	0,4	2,0
24	Kiskon-Perniönjoki	1	Koskenkoski	7,4	0,4	1,3
27	Paimionjoki	1	Askala	14	1,1	4,6
27	Paimionjoki	2	Juntola	14	1,6	3,9
27	Paimionjoki	3	Juva	14	1,3	5,0
34	Eurajoki	1	Pappilankoski	7,3	0,5	1,9
34	Eurajoki	2	Panelia	6,1	0,3	1,4
34	Eurajoki	3	Eurakoski	2,7	0,1	0,5
35	Kokemäenjoki	1	Harjavalta	26,5	73	390
35	Kokemäenjoki	2	Kolsi	12	45	173
35	Kokemäenjoki	3	Äetsä	6,2	14	70
35	Kokemäenjoki	4	Tyrvää	6,5	17	80
35	Kokemäenjoki	5	Melo	20	67	204
35	Kokemäenjoki	6	Siuro	3,1	0,6	3,0
35	Kokemäenjoki	7	Kyröskoski	21	12	44
35	Kokemäenjoki	8	Kukkurakoski	4,3	0,4	1,6
35	Kokemäenjoki	9	Käenkoski	14	2,1	4,7
35	Kokemäenjoki	10	Leppäskoski	11	0,5	2,2
35	Kokemäenjoki	11	Ala-Tammerkoski	3,5	3,9	15
35	Kokemäenjoki	12	Keski-Tammerkoski	7,0	8,4	32
35	Kokemäenjoki	13	Tampella	7,5	3,3	12
35	Kokemäenjoki	14	Finlayson	7,5	4,1	16
35	Kokemäenjoki	15	Soininkoski	8,0	1,4	5,7
35	Kokemäenjoki	16	Killinkoski	23	4,4	18
35	Kokemäenjoki	17	Vääräkoski	8,0	1,0	4,6
35	Kokemäenjoki	18	Ryöttö	8,0	1,0	4,5
35	Kokemäenjoki	19	Mäntänkoski	6,3	1,5	5,0
35	Kokemäenjoki	20	Valkeakoski	5,0	3,0	10

35	Kokemäenjoki	20	Valkeakoski	5,0	3,0	10
35	Kokemäenjoki	21	Korkeakoski	21	0,2	0,5
35	Kokemäenjoki	22	Porraskoski	6,0	0,2	0,7
35	Kokemäenjoki	23	Sallila	6,0	1,2	4,5
35	Kokemäenjoki	24	Vuolle	4,0	0,9	3,0
35	Kokemäenjoki	25	Vesikoski	5,1	0,6	2,0
35	Kokemäenjoki	26	Jokioinen	9,0	0,7	2,5
36	Karvianjoki	1	Makkarakoski	4,0	0,2	1,0
36	Karvianjoki	2	Sahakoski	5,9	0,2	1,0
36	Karvianjoki	3	Lankoski	8,5	0,4	2,5
36	Karvianjoki	4	Vatajankoski	12	0,8	4,0
36	Karvianjoki	5	Jyllinkoski	8,0	0,5	1,0
42	Kyrönjoki	1	Voitila	2,5	0,1	0,2
42	Kyrönjoki	2	Hiirikoski	4,0	0,5	2,0
42	Kyrönjoki	3	Pitkämö	29	6,3	24
42	Kyrönjoki	4	Niiles	13	1,1	3,7
42	Kyrönjoki	5	Kyrkösjärvi	42	8,0	18
42	Kyrönjoki	6	Kalajärvi	13	1,6	3,5
43	Oravaistenjoki	1	Hammarfallet	10	0,1	0,9
44	Lapuanjoki	1	Stadsfors	9,0	4,5	12
44	Lapuanjoki	2	Jylhänkoski	6,0	0,3	1,2
44	Lapuanjoki	3	Hourunkoski	7,3	0,8	3,2
44	Lapuanjoki	4	Mäkelänkoski	9,0	0,7	3,0
44	Lapuanjoki	5	Hirvikoski	50	8,0	19,6
44	Lapuanjoki	6	Karsinakoski	7,5	0,1	0,7
47	Ähtävänjoki	1	Herrfors	3,6	0,7	3,0
47	Ähtävänjoki	2	Långfors	5,3	1,1	4,4
47	Ähtävänjoki	3	Värnum	5,5	1,3	4,2
47	Ähtävänjoki	4	Hattar	6,0	1,1	4,4
47	Ähtävänjoki	5	Finnholm	4,7	1,0	3,8
47	Ähtävänjoki	6	Björkfors	7,0	1,2	6,8
47	Ähtävänjoki	7	Kattilakoski	9,5	2,0	9,0
47	Ähtävänjoki	8	Hanhikoski	7,1	1,5	6,0
47	Ähtävänjoki	9	Koskenvarsi	26	0,8	4,0
49	Perhonjoki	1	Kaitfors	21	7,5	23
49	Perhonjoki	2	Pirttikoski	4,0	0,5	2,2
49	Perhonjoki	3	Pihlajamaa	9,5	0,5	1,7
49	Perhonjoki	4	Patana	12	0,7	2,0
49	Perhonjoki	5	Alajoenkoski	4,0	0,1	0,7
51	Lestijoki	1	Korpela	18	1,0	5,5
53	Kalajoki	1	Hamari	6,4	2,5	7,6
53	Kalajoki	2	Padinki	4,3	1,1	4,1

53	Kalajoki	2	Padinki	4,3	1,1	4,1
53	Kalajoki	3	Oksava	11	2,8	8,0
53	Kalajoki	4	Hinkua	20	6,0	10
54	Pyhäjoki	1	Hourunkoski	6,0	0,7	3,7
54	Pyhäjoki	2	Haapakoski	3,2	0,6	2,5
54	Pyhäjoki	3	Venetpalo	16	2,0	7,5
54	Pyhäjoki	4	Kalliokoski	6,0	0,7	3,0
54	Pyhäjoki	5	Vesikoski	7,1	0,7	3,2
57	Siikajoki	1	Pöyry	6,0	0,5	3,0
57	Siikajoki	2	Ruukki	3,1	0,1	0,7
57	Siikajoki	3	Uljua	15	4,0	12
57	Siikajoki	4	Kirkkokoski	2,0	0,1	0,7
59	Oulujoki	1	Merikoski	11	35	180
59	Oulujoki	2	Montta	12	43	185
59	Oulujoki	3	Pyhäkoski	32	129	575
59	Oulujoki	4	Pälli	14	51	235
59	Oulujoki	5	Ala-Utos	5,0	1,0	1,3
59	Oulujoki	6	Utanen	16	55	245
59	Oulujoki	7	Nuojua	22	81	355
59	Oulujoki	8	Jylhämä	11	57	200
59	Oulujoki	9	Leppikoski	11	21	75
59	Oulujoki	10	Pyhäntä	12	4,1	6,0
59	Oulujoki	11	Seitenoikea	21	31	130
59	Oulujoki	12	Aittokoski	30	45	125
59	Oulujoki	13	Ämmä	10	17	37
59	Oulujoki	14	Ämmäkoski	7,0	4,0	11
59	Oulujoki	15	Koivukoski 1&2	8,0	6,0	16
59	Oulujoki	16	Koivukoski 3	15	25	73
59	Oulujoki	17	Kallioinen	10	15	40
59	Oulujoki	18	Katerma	10	15	37
61	Iijoki	1	Raasakka	21	58	225
61	Iijoki	2	Maalismaa	18	33	164
61	Iijoki	3	Kierikki	18	38	159
61	Iijoki	4	Pahkakoski	21	34	170
61	Iijoki	5	Haapakoski	16	32	130
61	Iijoki	6	Pintamo	31	0,5	1,4
61	Iijoki	7	Taivalkoski	5,5	0,3	1,8
61	Iijoki	8	Soilu	28	1,8	5,0
65	Kemijoki	1	Isohaara	12	106	434
65	Kemijoki	2	Taivalkoski	15	133	529
65	Kemijoki	3	Ossauskoski	15	124	501
65	Kemijoki	4	Petäjäskoski	21	182	687

65	Kemijoki	5	Valajaskoski	12	101	365
65	Kemijoki	6	Permantokoski	24	13	51
65	Kemijoki	7	Vanttauskoski	22	83	424
65	Kemijoki	8	Kaihua	46	5,4	11
65	Kemijoki	9	Kaarni	18	1,2	2,0
65	Kemijoki	10	Juotas	21	3,7	8,0
65	Kemijoki	11	Pirttikoski	26	150	581
65	Kemijoki	12	Seitakorva	17	130	506
65	Kemijoki	13	Jumisko	96	30	93
65	Kemijoki	14	Kokkosniva	12	25	79
65	Kemijoki	15	Kurkiaska	13	27	83
65	Kemijoki	16	Kelukoski	7,0	9,8	38
65	Kemijoki	17	Matarakoski	7,0	11	31
65	Kemijoki	18	Vajukoski	16	21	69
65	Kemijoki	19	Kurittukoski	11	15	42
65	Kemijoki	20	Porttipahta	30	35	100
65	Kemijoki	21	Lokka	7,0	0,1	0,5
67	Tornionjoki	1	Portimokoski	17	11	34
67	Tornionjoki	2	Kaaranneskoski	16	2,5	10
67	Tornionjoki	3	Jolmankoski	5,0	0,5	1,2
71	Paatsjoki	1	Kirakkaköngäs	14	1,0	4,5
73	Koutajoki	1	Myllykoski	11	1,4	6,0
Laitosten kokonaismäärä / Total number of plants		221	Yhteensä / Total:		3 137	13 143
Oy Vesirakentaja referenssit / references		163				

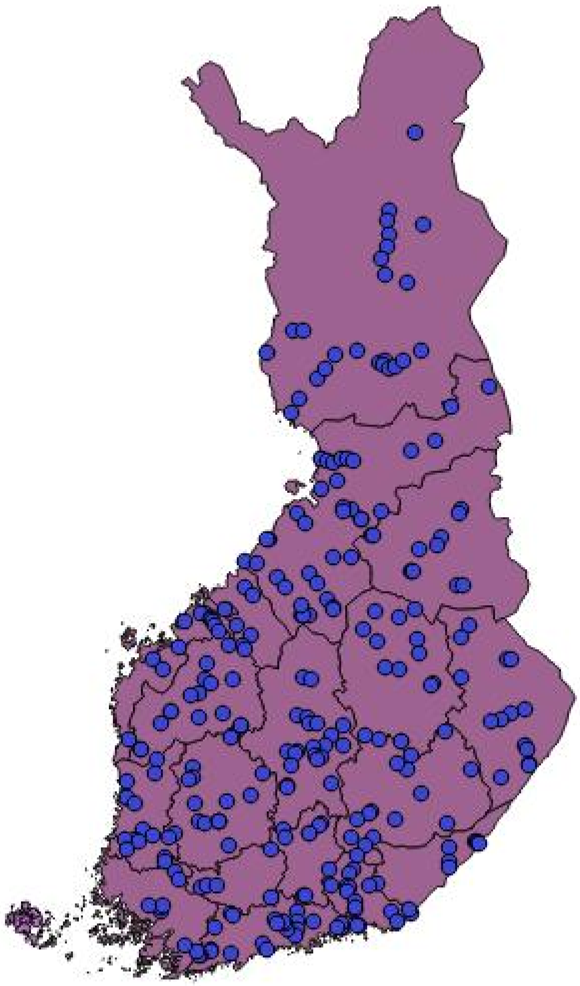


Figure 7 hydropower plants locations that are in table 11

Table 12 capacity in MW per region

NAME_2	VARNAME_2	Hydropower
Lapland	Lappi|Lappland	1221.200
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbot...	536.100
Kainuu	Kainuu|Kajanaland	321.100
South Karelia	Etelä-Karjala|Södra Karelen	243.750
Kymenlaakso	Kymenlaakso|Kymmenedalen	197.900
North Karelia	Pohjois-Karjala|Norra Karelen	174.200
Pirkanmaa	Pirkanmaa|Birkaland	143.950
Satakunta	Satakunta|Satakunda	122.700
Central Finland	Keski-Suomi|Mellersta Finland	37.000
Uusimaa	Itä-Uusimaa|Östra Nyland	36.100
North Savonia	Pohjois-Savo|Norra Savolax	35.300
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	31.500
Ostrobothnia	Österbotten|Pohjanmaa	21.350
Southern Savonia	Etelä-Savo|Södra Savolax	13.400
Finland Proper	Varsinais-Suomi|Egentliga Finland	5.850
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österb...	2.900
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	2.000
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	1.750

The table above represents each regions total capacity for production of energy in MW.

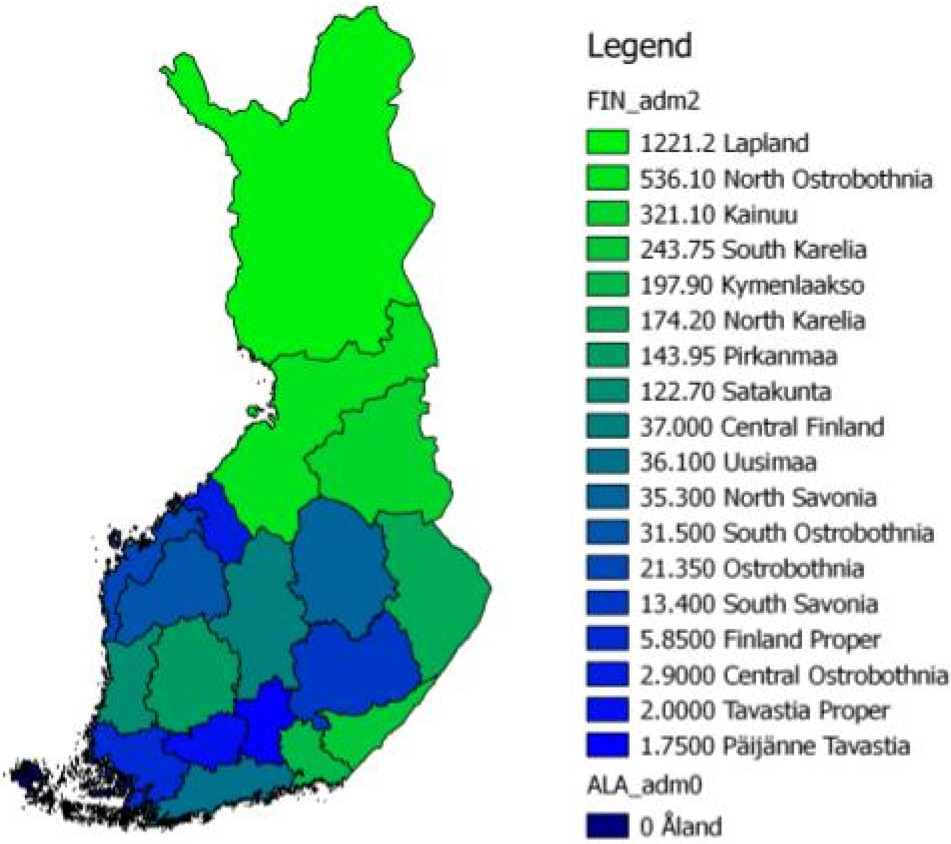


Figure 8 represents the total power each region produces in MW

Table 13 hydropower in PJ, TCE and Hh's

NAME_2	VARNAME_2	HP_PJ	HP_Hhs	HP_TCE
Lapland	Lappi|Lappland	38.511763200	578881.0	2102486.08300
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	16.906449600	254125.0	922979.68310
Kainuu	Kainuu|Kajanaland	10.126209600	152210.0	552823.68260
South Karelia	Etelä-Karjala|Södra Karelen	7.686900000	115544.0	419653.60520
Kymenlaakso	Kymenlaakso|Kymmenedalen	6.240974400	93810.0	340715.68600
North Karelia	Pohjois-Karjala|Norra Karelen	5.493571200	82575.0	299912.44320
Pirkanmaa	Pirkanmaa|Birkaland	4.539607200	68236.0	247832.35480
Satakunta	Satakunta|Satakunda	3.869467200	58163.0	211247.16870
Central Finland	Keski-Suomi|Mellersta Finland	1.166832000	17539.0	63701.26520
Uusimaa	Uusimaa|Nyland	1.138449600	17113.0	62151.77497
North Savonia	Pohjois-Savo|Norra Savolax	1.119528000	16828.0	61118.78148
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	0.993384000	14932.0	54232.15821
Ostrobothnia	Österbotten|Pohjanmaa	0.673293600	10120.0	36757.35168
Southern Savonia	Etelä-Savo|Södra Savolax	0.422582400	6352.0	23070.18794
Finland Proper	Varsinais-Suomi|Egentliga Finland	0.184485600	2773.0	10071.68652
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	0.091454400	1375.0	4992.80186
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.063072000	948.0	3443.31163
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.055188000	830.0	3012.89767

The table above shows the total energy produced in PJ, tonne of coal equivalent (TCE) and the energy provided to households (Hhs).

Calculation example for Lapland:

The total power of Lapland is 1 221.2 MW. It was taken for granted that the power plants production would be the entire year, which is 8 760 h not counting the hours lost to maintenance or reduced capacity due to a bad season because of less rain fall.

1 221.2 MW × 8 760 h = 10.698 TWh

10.698 TWh × 3 600 PJ/TWh = 38.5118 PJ

38.5118 PJ × 34 120.8424 TCE/PJ = 1314055.058 TCE

1314055.1158 TCE × 1.6 (power plant efficiency of 40%) = 2 102 488.9853 TCE

10.697712 TWh / 18480 kWh per household = 57 8881 Hh's

Tables, Figures and calculations for untapped potential hydropower

Table 14 Small scale hydropower in Finland (Pienvesivoimakartoitus, Minivesivoimasektori < 1MW)

Koski-inventoinnin ja KTM-PVV selvityksen rekisterin kattavat Suomen vesistöalueet

Vesistö-no:	Vesistön nimi	Vesistö F (km^2)	L (%)	Teoreettinen teho Pm (MW) *)	Teoreettinen vuosienergia Ema (GWh/a) **)	Huom.
1	Jänisjoki	3861	10.1	7.74	67.81	
2	Kiteenjoki - Tohmajoki	1595	5.6	0.08	0.73	
3	Hiitolanjoki	1415	12.5	2.40	21.04	
4	Vuoksen vesistöalue	68501	19.8	354.00	3101.03	
5	Juustilanjoki	296	3.6			ei sisälly
6	Hounijoki	622	2.9	0.00	0.00	
7	Tervajoki	204	3.9	0.02	0.15	
8	Vilajoki	344	6.3	0.20	1.74	
9	Urpalanjoki	557	5.3	0.53	4.62	
10	Vaalimaanjoki	245	3.1	0.31	2.68	
11	Vironjoki	357	3.8	0.51	4.45	
12	Vehkajoki	380	5.8	0.12	1.07	
13	Summajoki	569	2.2	0.84	7.34	
14	Kymijoki - Kymmene älv	37159	18.3	268.97	2356.19	
15	Taasianjoki - Tesjö å	530	0.5	0.44	3.89	
16	Koskenkylänjoki - Forsby å	895	4.4	2.14	18.72	
17	Ilolanjoki - Illby å	309	3.6	0.26	2.29	
18	Porvoonjoki - Borgå å	1273	1.3	4.63	40.53	
19	Mustijoki - Svarts å	783	1.5	3.11	27.21	
20	Sipoonjoki - Sibbo å	220	0.6	0.08	0.70	
21	Vantaanjoki - Vanda å	1686	2.2	5.43	47.59	
22	Siuntionjoki - Sjunde å	487	5.2	0.66	5.78	
23	Karjaanjoki - Kasris å (Svartå)	2046	12.2	9.45	82.74	
24	Kiskonjoki + Perniönjoki	1047	5.7	2.19	19.15	
25	Uskelanjoki	566	0.6	1.31	11.48	
26	Halikonjoki	306	0.0	0.68	5.91	
27	Paimionjoki - Pemar å	1088	1.6	11.43	100.13	
28	Aurajoki - Aura å	874	0.2	2.28	20.00	
29	Hirvijoki	284	0.0	0.15	1.29	
30	Mynäjoki	288	0.3	0.96	8.44	
31	Laajoki	393	2.0	1.07	9.36	
32	Sirppujoki	438	1.8	0.15	1.33	
33	Lapinjoki	462	4.2	0.86	7.57	
34	Eurajoki	1336	12.9	3.93	34.38	
35	Kokemäenjoki - Kumoälv	27046	11.0	188.12	1647.90	
36	Karvianjoki	3438	4.6	15.16	132.84	
37	Lapväärtinjoki - Lappfjärds å	1098	0.2	3.37	29.55	
38	Teuvanjoki - Tjöck å	542	0.1	1.07	9.34	
39	Närpiönjoki - Närpes å	992	0.4	1.83	16.02	

*) Teoreettinen teho Pm (MW) = MQ*H*9.81/1000

**) Teoreettinen vuosienergia Ema (GWh/a) = Pm*8760/1000

Vesistö-no:	Vesistön nimi	Vesistö F (km²)	L (%)	Teoreettinen teho Pm (MW) *)	Teoreettinen vuosienergia Ema (GWh/a) **)	Huomautus
40	Maalahdenjoki - Malax å	500	0.0	0.29	2.55	
41	Laihianjoki - Toby å	506	0.3	0.23	2.02	
42	Kyrönjoki - Kyro älv	4923	1.2	20.03	175.49	
43	Oravaistenjoki-Kimojoki-Kimo å	196	2.2	0.17	1.47	
44	Lapuanjoki - Lappo å	4122	2.9	16.16	141.58	
45	Kovjoki	292	0.7	0.06	0.52	
46	Purmojoki - Purmo å	864	2.4	2.20	19.25	
47	Ähtävänjoki - Esse å	2054	9.8	7.70	67.47	
48	Kruunupyynjoki - Kronobyå	788	2.8	3.40	29.80	
49	Perhonjoki - Perho å	2524	3.4	18.79	164.58	
50	Kälviänjoki	324	0.5	0.03	0.28	
51	Lestijoki	1373	6.2	8.61	75.42	
52	Pöntiönjoki	207	0.4	0.00	0.00	
53	Kalajoki	4247	1.8	22.17	194.23	
54	Pyhäjoki	3712	5.2	27.39	239.92	
55	Liminkaojanjoki	187	0.8	0.04	0.39	
56	Piehinginjoki	176	0.4	0.04	0.32	
57	Siikajoki	4318	2.2	21.29	186.50	
58	Temmesjoki	1181	0.5	0.23	2.00	
59	Oulujoki - Ute älv	22841	11.5	405.62	3553.19	
60	Kiiminginjoki	3814	3.0	35.32	309.41	
61	Iijoki	14191	5.7	256.67	2248.43	
62	Olhavanjoki	326	0.6			ei sisälly
63	Kuivajoki	1356	2.7	10.06	88.09	
64	Simojoki	3160	5.7	44.88	393.17	
65	Kemijoki - Kemiälv	51127	4.3	811.40	7107.87	
66	Kaakamajoki	478	0.4	0.00	0.00	
67	Tornionjoki+Muonionj.-Torne älv	40131	4.6	706.02	6184.74	
68	Tenojoki - Tana	14891	3.1	87.71	768.30	
69	Näätämöjoki - Neiden älv	2962	11.4	16.24	142.28	
70	Uutuanjoki - Munk älv	403	9.1			ei sisälly
71	Paatsjoki - Pasvik älv	14512	12.4	55.49	486.05	
72	Tuulomajoen latvavesistöalue	3241	1.3	7.96	69.75	
73	Koutajoen latvavesistöalue	5010	12.2	39.35	344.66	
74	Vienan Kemin latvavesistöalue	1415	16.7	0.50	4.37	
81	Suomenlahden rannikkoalue			0.13	1.10	
82	Saaristomeren rannikkoalue			0.50	4.41	
83	Selkämeren rannikkoalue			0.18	1.55	
84	Perämeren rannikkoalue			0.11	1.01	
85	Ruotsin ja Norjan raja-alueet					ei sisälly
86	Venäjän raja-alue			0.02	0.13	
	Kaikki vesistöt yhteensä	**376884**		**3523.44**	**30865.32**	

*) Teoreettinen teho Pm (MW) = MQ*H*9.81/1000

**) Teoreettinen vuosienergia Ema (GWh/a) = Pm*8760/1000

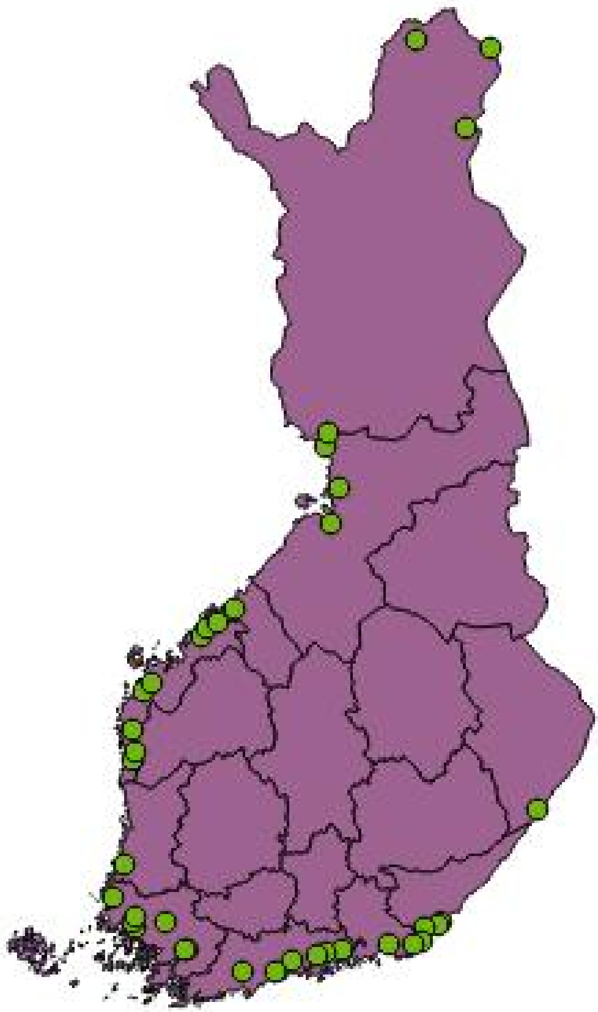


Figure 9 the locations of potential hydropower by region

Table 15 the potential of hydropower with their coordinates, theoretical power and energy

	Province	Longitude	Latitude	Power_MW	Energy_GWh
0	North_Karelia	30.27772800000...	62.00187600000...	0.080000000000...	0.730000000000...
1	South_Karelia	28.31670799999...	60.85908400000...	0.000000000000...	0.000000000000...
2	South_Karelia	28.21918399999...	60.82431199999...	0.020000000000...	0.150000000000...
3	South_Karelia	27.97604000000...	60.79162600000...	0.200000000000...	1.740000000000...
4	Kymenlaakso	27.90567199999...	60.64974699999...	0.530000000000...	4.620000000000...
5	Kymenlaakso	27.75049299999...	60.62633600000...	0.310000000000...	2.680000000000...
6	Kymenlaakso	27.21408299999...	60.61525900000...	0.120000000000...	1.070000000000...
7	Uusimaa	26.26970199999...	60.52002600000...	0.440000000000...	3.890000000000...
8	Uusimaa	25.94123600000...	60.49132000000...	2.140000000000...	18.71999999999...
9	Uusimaa	25.77222199999...	60.44927400000...	0.260000000000...	2.290000000000...
10	Uusimaa	25.30307000000...	60.39399600000...	0.080000000000...	0.720000000000...
11	Uusimaa	24.95986699999...	60.26877199999...	5.430000000000...	47.59000000000...
12	Uusimaa	24.26847100000...	60.23229200000...	0.660000000000...	5.780000000000...
13	Finland_Proper	23.15730900000...	60.39938500000...	1.310000000000...	11.48000000000...
14	Finland_Proper	23.07084400000...	60.39528500000...	0.680000000000...	5.910000000000...
15	Finland_Proper	22.59168100000...	60.66289799999...	2.280000000000...	20.00000000000...
16	Finland_Proper	22.01891900000...	60.55901200000...	0.150000000000...	1.290000000000...
17	Finland_Proper	21.92181499999...	60.62974200000...	0.960000000000...	8.440000000000...
18	Finland_Proper	21.98543600000...	60.67379700000...	1.070000000000...	9.359999999999...
19	Finland_Proper	21.50452299999...	60.84190999999...	0.150000000000...	1.330000000000...
20	Satakunta	21.63940200000...	61.18038700000...	0.860000000000...	7.570000000000...
21	Ostrobothnia	21.52962099999...	62.25670399999...	3.370000000000...	29.55000000000...
22	Ostrobothnia	21.55712300000...	62.34262300000...	1.070000000000...	9.340000000000...
23	Ostrobothnia	21.42937500000...	62.55588399999...	1.830000000000...	16.02000000000...
24	Ostrobothnia	21.57401200000...	62.93992699999...	0.290000000000...	2.550000000000...
25	Ostrobothnia	21.68658500000...	63.04274399999...	0.230000000000...	2.020000000000...
26	Ostrobothnia	22.67718000000...	63.55596100000...	0.060000000000...	0.520000000000...
27	Ostrobothnia	22.80866700000...	63.64384799999...	2.200000000000...	19.25000000000...
28	Ostrobothnia	23.05095800000...	63.72509199999...	3.400000000000...	29.80000000000...
29	Central_Ostrobo...	23.34572100000...	63.88264000000...	0.030000000000...	0.280000000000...
30	Northern_Ostrob...	25.40504100000...	64.82884799999...	0.230000000000...	2.000000000000...
31	Northern_Ostrob...	25.53150600000...	65.19849899999...	35.32000000000...	309.4100000000...
32	Northern_Ostrob...	25.18455900000...	65.60246300000...	10.06000000000...	88.09000000000...
33	Lappi	25.19118999999...	65.72463899999...	44.88000000000...	393.1700000000...
34	Lappi	26.87715000000...	69.76617500000...	87.70999999999...	768.2999999999...
35	Lappi	29.01593300000...	69.70741800000...	16.23999999999...	142.2800000000...
36	Lappi	28.41768700000...	68.90053799999...	55.49000000000...	486.0500000000...

Table represents the potential of hydropower with their coordinates, theoretical power and energy.

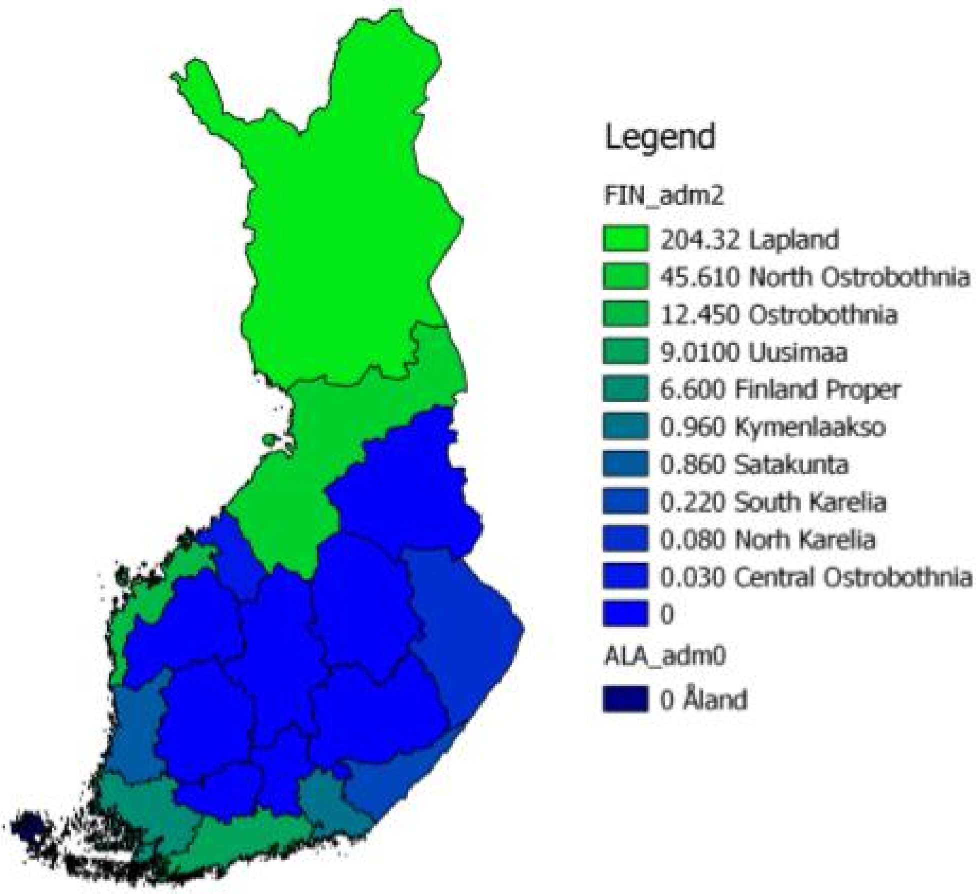


Figure 10 the potential of hydropower in MW

The map above represents the potential of hydropower in MW.

Table 16 small scale hydropower in MW

NAME_2	VARNAME_2	Pot_Hydro
Lapland	Lappi|Lappland	204.320
Northern Ostrob...	Pohjois-Pohjanmaa|Norra Österbotten	45.610
Ostrobothnia	Österbotten|Pohjanmaa	12.450
Uusimaa	Itä-Uusimaa|Östra Nyland	9.010
Finland Proper	Varsinais-Suomi|Egentliga Finland	6.600
Kymenlaakso	Kymenlaakso|Kymmenedalen	0.960
Satakunta	Satakunta|Satakunda	0.860
South Karelia	Etelä-Karjala|Södra Karelen	0.220
North Karelia	Pohjois-Karjala|Norra Karelen	0.080
Central Ostrobot...	Keski-Pohjanmaa|Mellersta Österbotten	0.030
Southern Savonia	Etelä-Savo|Södra Savolax	0.000
Kainuu	Kainuu|Kajanaland	0.000
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.000
North Savonia	Pohjois-Savo|Norra Savolax	0.000
Central Finland	Keski-Suomi|Mellersta Finland	0.000
Pirkanmaa	Pirkanmaa|Birkaland	0.000
Southern Ostrob...	Etelä-Pohjanmaa|Sydösterbotten	0.000
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.000

Table 17 power converted to PJ, TCE and Hh’s

NAME_2	VARNAME_2	PHP_PJ	PHP_TCE	PHP_Hhs
Lapland	Lappi|Lappland	6.44343552	351768.7164000...	96853.0
Northern Ostrobothnia	Pohjois-Pohjanmaa|Norra Österbotten	1.43835696	78524.721780000	21620.0
Ostrobothnia	Österbotten|Pohjanmaa	0.39262320	21434.614910000	5902.0
Uusimaa	Uusimaa|Nyland	0.28413936	15512.118900000	4271.0
Finland Proper	Varsinais-Suomi|Egentliga Finland	0.20813760	11362.928390000	3129.0
Kymenlaakso	Kymenlaakso|Kymmenedalen	0.03027456	1652.789584000	455.0
Satakunta	Satakunta|Satakunda	0.02712090	1480.624002000	407.0
South Karelia	Etelä-Karjala|Södra Karelen	0.00693792	378.764279600	104.0
North Karelia	Pohjois-Karjala|Norra Karelen	0.00252288	137.732465300	38.0
Central Ostrobothnia	Keski-Pohjanmaa|Mellersta Österbotten	0.00094608	51.649674490	14.0
Southern Savonia	Etelä-Savo|Södra Savolax	0.00000000	0.000000000	0.0
Kainuu	Kainuu|Kajanaland	0.00000000	0.000000000	0.0
Tavastia Proper	Kanta-Häme|Egentliga Tavastland	0.00000000	0.000000000	0.0
North Savonia	Pohjois-Savo|Norra Savolax	0.00000000	0.000000000	0.0
Central Finland	Keski-Suomi|Mellersta Finland	0.00000000	0.000000000	0.0
Pirkanmaa	Pirkanmaa|Birkaland	0.00000000	0.000000000	0.0
Southern Ostrobothnia	Etelä-Pohjanmaa|Sydösterbotten	0.00000000	0.000000000	0.0
Päijänne Tavastia	Päijät-Häme|Päijänne Tavastland	0.00000000	0.000000000	0.0

The table above shows the power converted to energy and its equivalents. The values are theoretical values. For example Lapland has the potential of producing 6.44 PJ of energy converted to tons of coal equivalent is 351 768.7 TCE. The same energy is converted to represent how many households this energy is able to provide to an average household that use 18 480 kWh/a (96 853 Hh’s).

Example of converting power to energy is shown below:

Lapland has the capacity of 204.320 MW.

204.320 MW × 8 760h = 1.7898432 TWh

6.44343552 TWh × 3 600 PJ/TWh = 6.44343552 PJ

6.4434552 PJ × 34 120.842 375 TCE/PJ = 219 856.1192 TCE

219 856.1192 TCE × 1.6 (efficiency of 40% coal power plant) = 351 769.7908 TCE

1.789432 TWh / 18 480 kWh/ Hh’s = 96 830 Hh’s

Electrical consumption regionally

Table 18 electrical usage and consumer population regionally

VUOSI - Year 2014 **MAAKUNTA - Region** GWh	ASUMINEN JA MAATALOUS Housing and agriculture	TEOLLISUUS Industry	PALVELUT JA RAKENTAMINEN Service and building	YHTEENSÄ Total	KÄYTTÄJÄT Consumers 1000 kpl - pc
Uusimaa	5 447	4 354	5 866	15 668	918
Varsinais-Suomi	2 103	1 254	1 464	4 821	267
Satakunta	930	3 759	948	5 638	154
Kanta-Häme	820	717	600	2 137	117
Pirkanmaa	1 974	2 510	1 441	5 925	327
Päijät-Häme	845	728	627	2 199	139
Kymenlaakso	780	2 821	900	4 501	126
Etelä-Karjala	532	4 253	476	5 261	94
Etelä-Savo	774	392	488	1 654	127
Pohjois-Savo	1 036	1 334	760	3 130	157
Pohjois-Karjala	724	1 471	472	2 668	116
Keski-Suomi	1 125	3 724	820	5 669	185
Etelä-Pohjanmaa	943	528	576	2 047	124
Pohjanmaa	1 149	1 566	492	3 207	120
Keski-Pohjanmaa	319	1 551	225	2 095	41
Pohjois-Pohjanmaa	1 711	2 917	1 242	5 870	244
Kainuu	350	400	307	1 056	57
Lappi	1 084	4 945	789	6 819	139
Ahvenanmaa	135	26	103	264	24
Yhteensä - Total	**22 781**	**39 250**	**18 597**	**80 628**	**3 477**

The table above shows the electrical consumption regionally in housing, agriculture, industry services and buildings in GWh. It also represents the amount of electrical consumers in each region.